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Semiconductor Group

The Optoelectronics Data Book

for Design Engineers

Fourth Edition

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The Optoelectronics Data Book

for Design Engineers

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IMPORTANT NOTICES

Texas Instruments reserves the right to make changes at any time in order to improve design and to supply the best product possible.

TI cannot assume any responsibility for any circuits shown or represent that they are free from patent infringement.

Information contained herein supercedes previously published data on optoelectronics devices from TI, including data book CC-419.

THE OPTOELECTRONICS DATA BOOK

Few people in the electronics industry realize that optoelectronics technology has a history that precedes the invention of the integrated circuit. It is also a relatively unknown fact that Texas Instruments was a pioneer in the development and manufacture of some of the first optoelectronic components, viz infrared detectors and photovoltaic solar cells, back in 1957.

During the past nineteen years TI has continued to develop and build optoelectronic devices and assemblies for end applications in the space, military, computer, industrial, and consumer industries. TI opto devices have helped to revolutionize the industry and to make it easier for the design engineer to accomplish his job.

In addition to offering the most experience, TI also provides the most complete line of standard opto products in the world. This ensures that design engineers can obtain more answers to questions involving circuitry and operating conditions by contacting TI.

If the most experience and the largest product line are not enough, TI also offers a locally based field sales engineering staff to assist design engineers. In most major cities throughout the U.S. and other countries there is a field sales engineer who has been trained as a specialist in opto products. His job is to provide the right product recommendations after considering all of the facts.

To complete the service aspect, TI has a world-wide distributor network that stocks almost 100 standard opto devices and assemblies. This means that design engineers can obtain fast delivery on small quantities required for initial circuit evaluation and purchasing departments can be assured of a local source of supply for production quantities.

It is the purpose of this data book to better acquaint both engineers and buyers with TI opto products and capabilities. It offers the user a categorized listing of optoelectronic data sheets, application reports, and product bulletins for more than 250 standard devices including 38 new types not included in the second edition of this data book. Each product section has a quick reference guide that lists the key electrical parameters and features for products in that section.

To further assist the user, there is an interchangeability guide that lists more than 800 optoelectronics devices built by other manufacturers, along with the nearest TI equivalent devices. There is also a glossary of optoelectronic terminology to answer questions on optoelectronic terms and phrases.

We feel that this data book is the most complete publication of its kind. It was compiled and edited with the objective of making your job easier.

General Information

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ALPHANUMERIC INDEX

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†Redesignated 4N41

GLOSSARY
OPTOELECTRONIC TERMS AND DEFINITIONS

1

Introduction

This glossary contains letter symbols, abbreviations, terms, and definitions commonly used with optoelectronic devices. Most of the information was obtained from JEDEC Publication No. 77A.

Index to Glossary by Symbols and Abbreviations

APD	Avalanche photodiode
B	Demodulation bandwidth
E_e	Irradiance
E_v	Illuminance
f_{mod}	Modulation frequency
H	Irradiance
$I_{C(off)}$	Off-state collector current
$I_{C(on)}$	On-state collector current
I_D	Dark current
I_e	Radiant intensity
I_L	Light current
IRED	Infrared-emitting diode
I_v	Luminous intensity
L_e	Radiance
L_v	Luminance
LED	Light-emitting diode
NEP	Noise equivalent power (spectral density)
P_n	Noise equivalent power (spectral density)
P_O	Radiant flux or power output
Q_e	Radiant energy
Q_v	Luminous energy
R_e	Radiant responsivity
R_v	Luminous responsivity
sr	Steradian
t_d	Delay time
t_f	Fall time
t_f	Radiant pulse fall time
t_r	Radiant pulse rise time
t_r	Rise time
t_s	Storage time
V_F	Forward voltage
VLED	Visible-light-emitting diode
Δf	Noise equivalent bandwidth
$\Delta\lambda$	Spectral bandwidth
θ_{HI}	Half-intensity beam angle
λp	Wavelength at peak emission
Φ_e	Radiant flux
Φ_v	Luminous flux

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Units of Measurement

Symbol	Unit	Note
A	ampere†	
Å	angstrom	1 Å = 10^{-10} m = 10^{-4} μm = 0.1 nm
cd	candela†	1 cd = 1 lm/sr
cd/ft^2	candala/foot^2	1 cd/ft^2 = 10.76391 cd/m^2
cd/m^2	candela/meter^2†	
°C	degree Celsius	
°K		See K
ft	foot	1 ft = 0.3048 m (exactly)
fc	footcandle	1 fc = 1 lm/ft^2 = 10.76391 lx
fL	footlambert	1 fL = (1/π) cd/ft^2 = 3.426259 cd/m^2
Hz	hertz†	
in	inch	1 in = 2.54 cm (exactly)
K	kelvin†	Formerly °K, degree Kelvin
L	lambert	1 L = 3183.099 cd/m^2
lm	lumen†	
lx	lux†	1 lx = 1 lm/m^2
m	meter†	
μ	micron	The equivalent unit μm is preferred
nt	nit	1 nt = 1 cd/m^2
ph	phot	1 ph = 1 lm/cm^2
Ω	ohm†	
s	second†	
sr	steradian†	
sb	stilb	1 sb = 1 cd/cm^2
V	volt†	
W	watt†	

†International System (SI) units.

Metric Multipliers

Many of the preceding unit symbols can be combined with the metric multipliers which follow.

Symbol	Prefix	Multiple
T	tera	10^{12}
G	giga	10^{9}
M	mega	10^{6}
k	kilo	10^{3}
h	hecto	10^{2}
da	deka	10
d	deci	10^{-1}
c	centi	10^{-2}
m	milli	10^{-3}
μ	micro	10^{-6}
n	nano	10^{-9}
p	pico	10^{-12}
f	femto	10^{-15}
a	atto	10^{-18}

GLOSSARY
OPTOELECTRONIC TERMS AND DEFINITIONS

1

Terms and Definitions

Avalanche Photodiode (APD)

A photodiode that is intended to take advantage of avalanche multiplication of photocurrent. As the reverse-bias voltage approaches the breakdown voltage, hole-electron pairs created by absorbed photons acquire sufficient energy to create additional hole-electron pairs when they collide with substrate atoms; thus a multiplication of signal current is achieved.
NOTE: APD's are especially suited for low-noise and/or high-speed applications.

Axis of Measurement

The direction from the source of radiant energy, relative to the mechanical axis, in which the measurement of radiometric and or spectroradiometric characteristics is performed.

Beam-Lead Phototransistor

A phototransistor chip with thick-film leads formed on the chip that project cantilever-style beyond the chip periphery for attachment to a separate substrate.
NOTE: When assembled into arrays and mounted on a ceramic substrate, beam-lead phototransistor arrays offer accurate spacing on centers too close for conventional discrete packages and too far apart for monolithic arrays; see TI Bulletin CB-128 for further information.

Brightness

See Luminance

Color Temperature

The temperature of a blackbody having the same visible color as that of a given non-blackbody radiator.
TYPICAL UNIT: K (formerly °K).

Conversion Efficiency (of a Photon-Emitting Device)

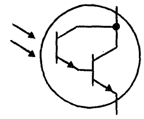
The ratio of maximum available luminous or radiant flux output to total input power.

Dark Current (I_D)

The current that flows through a photosensitive device in the dark condition.
NOTE: The dark condition is attained when the electrical parameter under consideration approaches a value that cannot be altered by further irradiation shielding.

Darlington-Connected Phototransistor

A phototransistor the collector and emitter of which are connected to the collector and base, respectively, of a second transistor. The emitter current of the input transistor is amplified by the second transistor and the device has very high sensitivity to illumination or irradiation.
GRAPHIC SYMBOL:



NOTE: The base region(s) may or may not be brought out as (an)electrical terminal(s).

D-C Transfer Ratio (of an Opto-coupler)

The ratio of the dc output current to the dc input current.

Delay Time (t_d)

The time interval from the point at which the leading edge of the input pulse has reached 10% of its maximum amplitude to the point at which the leading edge of the output pulse has reached 10% of its maximum amplitude.

Demodulation Bandwidth (B)

The frequency interval in which the demodulated output of a photodetector, or a system including a photodetector, is not more than 3 dB below the midband output. Midband output is the output in the region of flat response or the average output over a specific frequency range.

Electroluminescence

The direct conversion of electrical energy into visible radiation.

Fall Time (t_f)

The time duration during which the trailing edge of a pulse is decreasing from 90% to 10% of its maximum amplitude.

Forward Voltage (V_F)

The voltage across a semiconductor diode associated with the flow of forward current. The p-region is at a positive potential with respect to the n-region.

Gain-Bandwidth Product (of an Avalanche Photodiode)

The gain times the frequency of measurement when the device is biased for maximum obtainable gain.

Half-Intensity Beam Angle (θ_{HI})

The angle within which the radiant intensity is not less than half of the maximum intensity.

Hexadecimal Display

A solid-state display capable of exhibiting numbers 0 through 9 and alpha characters A through F.
NOTE: The TIL311 and TIL505 are hexadecimal displays each with an integral TTL circuit that will accept, store, and display 4-bit binary data.

Illuminance (Illumination) (E_v)

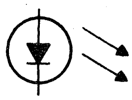
The luminous flux density incident on a surface; the quotient of the flux divided by the area of illuminated surface.
TYPICAL UNITS: lm/ft^2, $lx = lm/m^2$. $1\ lm/ft^2 = 10.76391\ lx$.

Infrared Emission

Radiant energy that is characterized by wavelengths longer than visible red, i.e., about 0.78 μm to 100 μm.

Infrared-Emitting Diode (IRED)

A diode capable of emitting radiant energy, in the infrared region of the spectrum, resulting from the recombination of electrons and holes.
NOTE: TI manufactures GaAs and GaAsP radiant-energy sources that emit in the 0.82-μm to 0.94-μm portion of the near-infrared region. These emitters are spectrally matched with TI silicon phototransistors and photodiodes.
GRAPHIC SYMBOL:



Irradiance (E_e, formerly H)

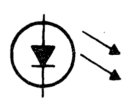
The radiant flux density incident on a surface; the quotient of the flux divided by the area of irradiated surface.
TYPICAL UNITS: W/ft^2, W/m^2. 1 W/ft^2 = 10.76391 W/m^2.

Light Current (I_L)

The current that flows through a photosensitive device, such as a phototransistor or a photodiode, when it is exposed to radiant energy.

Light-Emitting Diode (LED)

A diode capable of emitting luminous energy resulting from the recombination of electrons and holes.
NOTE: In popular usage, this term is sometimes used for infrared-emitting diodes.
GRAPHIC SYMBOL:



Luminance (L_v) (Photometric Brightness)

The luminous intensity of a surface in a given direction per unit of projected area of the surface as viewed from that direction.
TYPICAL UNITS: fL, cd/ft^2, cd/m^2. 1 fL = (1/π) cd/ft^2 = 3.426259 cd/m^2.

Luminous Energy (Q_v)

Energy traveling in the form of visible radiation.
TYPICAL UNITS: lm · s

Luminous Flux (Φ_v)

The time rate of flow of luminous energy.
TYPICAL UNIT: lm
NOTE: Luminous flux is related to radiant flux by the eye-response curve of the International Commission on Illumination (CIE). At the peak response (λ = 555 nm), 1 W = 680 lm.

Luminous Intensity (I_V)

Luminous flux per unit solid angle in a given direction.
TYPICAL UNIT: cd. 1 cd = 1 lm/sr.

Luminous Responsivity (R_V)

The quotient of the rms value of the fundamental component of the electrical output divided by the rms value of the fundamental component of the luminous flux of a specified distribution.
TYPICAL UNITS: V/lm, A/lm

Modulation Frequency (f_{mod})

The frequency of modulation of the luminous or radiant flux.

Noise Equivalent Bandwidth (Δf)

The equivalent bandwidth of a flat (or white) sharp-cutoff noise spectrum, having the same maximum value and containing the same noise power as the actual broadband output noise power of the device or circuit.
TYPICAL UNIT: Hz

Noise Equivalent Power (P_n or NEP)

The rms value of the fundamental component of a modulated radiant flux incident on the detector area that will produce a signal (voltage or current) at the detector output that is equal to the broadband rms noise (voltage or current).
TYPICAL UNIT: W
NOTE: The noise equivalent power equals the broadband output noise (voltage or current) divided by the responsivity (in volts/watt or amperes/watt).

Noise Equivalent Power (P_n or NEP) (Spectral Density)

The noise equivalent power in a one-Hertz bandwidth at the detector output.
TYPICAL UNIT: $W/Hz^{1/2}$
NOTE: The noise equivalent power spectral density equals the noise equivalent power divided by the square root of the noise bandwidth.

Off-State Collector Current ($I_{C(off)}$) (of an Opto-coupler)

The output current when the input current is zero.

On-State Collector Current ($I_{C(on)}$) (of an Opto-coupler)

The output current when the input current is above the threshold level.
NOTE: An increase in the input current will usually result in a corresponding increase in the on-state collector current.

Optical Axis

A line about which the radiant-energy pattern is centered.
NOTES: 1. The radiant-energy pattern may be nonsymmetrical.
2. The optical axis may deviate from the mechanical axis.

Opto-coupler (Optically Coupled Isolator, Photo-coupler)

A device designed for the transformation of electrical signals by utilizing optical radiant energy so as to provide coupling with electrical isolation between the input and the output.
NOTE: As manufactured by Texas Instruments, these devices consist of a gallium arsenide infrared-emitting diode and a silicon phototransistor and provide high-voltage isolation between separate pairs of input and output terminals.

Optoelectronic Device

A device that is responsive to or that emits or modifies coherent or noncoherent electromagnetic radiation in the visible, infrared, and/or ultraviolet spectral regions; or a device that utilizes such electromagnetic radiation for its internal operation.

Photocurrent

The difference between light current (I_L) and dark current (I_D) in a photodetector.

Photocurrent Gain (of an Avalanche Photodiode)

The ratio of photocurrent at high bias voltage to that at low bias voltage. (See also avalanche photodiode definition).

Photodetector, Photosensitive Device

A device that is responsive to electromagnetic radiation in the visible, infrared, and/or ultraviolet spectral regions.

Photodiode

A diode that is intended to be responsive to radiant energy.
GRAPHIC SYMBOLS:

NOTE: The photodiode is characterized by linearity between the input radiation and the output current. It has faster switching speeds than a phototransistor.

Photometric Axis

See Axis of Measurement.

Photometric Brightness

See Luminance.

Photon

A quantum (the smallest possible unit) of radiant energy; a photon carries a quantity of energy equal to Planck's constant (6.6256 X 10^{-27} erg•seconds) times the frequency.

Phototransistor

A transistor (bipolar or field-effect) that is intended to be responsive to radiant energy.
NOTE: The base region or gate may or may not be brought out as an external terminal.
GRAPHIC SYMBOLS:

Quantum Efficiency (of a Photosensitive Device)

The number of effective electron-hole pairs produced within the device for each incident photon. For devices that internally amplify or multiply the electron-hole pairs (such as phototransistors or avalanche photodiodes), the effect of the gain is to be excluded from quantum efficiency.

Radiance (L_e)

The radiant intensity of a surface in a given direction per unit of projected area of the surface as viewed from that direction.
TYPICAL UNIT: $W \cdot sr^{-1} m^{-2}$.

Radiant Energy (Q_e)

Energy traveling in the form of electromagnetic waves.
TYPICAL UNITS: W•s, J

Radiant Flux or Power Output (Φ_e or P_O)

The time rate of flow of radiant energy.
TYPICAL UNITS: W

Radiant Intensity (I_e)

Radiant flux per unit solid angle in a given direction.
TYPICAL UNIT: W/sr

Radiant Pulse Fall Time (t_f)

The time required for a radiometric quantity to change from 90% to 10% of its peak value for a step change in electrical input.

Radiant Pulse Rise Time (t_r)

The time required for a radiometric quantity to change from 10% to 90% of its peak value for a step change in electrical input.

Radiant Responsivity (R_e)

The quotient of the rms value of the fundamental component of the electrical output divided by the rms value of the fundamental component of the radiant flux of a specified distribution.
TYPICAL UNITS: V/W, A/W

Rise Time (t_r)

The time duration during which the leading edge of a pulse is increasing from 10% to 90% of its maximum amplitude.

Spectral Bandwidth ($\Delta\lambda$)

The wavelength interval in which the spectral concentration of a photometric or radiometric quantity is not less than half of its maximum value.
TYPICAL UNITS: Å, μm, nm

Spectral Output

A description of the radiant-energy-emission or light-emission characteristic versus wavelength.
NOTE: This information is usually given by stating the wavelength at peak emission and the bandwidth between half-power points or by means of a curve.

Spectral Response (of a Photosensitive Device)

A description of the electrical-output characteristic versus wavelength of radiant energy incident upon the device.
NOTE: This information is usually given by means of a curve.

Steradian (sr)

A unit of solid angular measurement equal to the solid angle at the center of a sphere subtended by a portion of the surface area equal to the square of the radius; there are 4π steradians in a complete sphere. The number of steradians subtended by an angle θ is $2\pi(1-\cos 0.5\theta)$.

Storage Time (t_s)

The time interval from a point at which the trailing edge of the input pulse has dropped to 90% of its maximum amplitude to a point at which the trailing edge of the output pulse has dropped to 90% of its maximum amplitude.

Visible Emission

Radiant energy that is characterized by wavelengths of about 0.38 μm to 0.78 μm.

Visible-Light-Emitting Diode (VLED)

Synonym for Light-Emitting Diode.
NOTE: Strictly speaking, the adjective "visible" is redundant; however, this term is frequently used when there is a likelihood of confusion with infrared-emitting diodes.

Wavelength at Peak Emission (λ_p)

The wavelength at which the spectral radiant intensity is maximum.
TYPICAL UNITS: Å, μm, nm. 1 Å = 10^{-4} μm = 0.1 nm.

Interchangeability Guide

2

OPTOELECTRONICS INTERCHANGEABILITY GUIDE

The newly-revised interchangeability guide has been updated to include more than 800 standard optoelectronic devices and assemblies built by other domestic manufacturers.

This guide has been expanded to include a code letter system which designates the similarity between the other manufacturers' device and the nearest TI equivalent.

Code Definitions

A – TI device is electrically and mechanically equivalent
B – Minor electrical differences exist
C – Minor mechanical differences exist
D – Significant electrical differences exist
E – Significant mechanical differences exist

Since optoelectronics is a relatively young industry, it is possible that different devices offered by two or more manufacturers will satisfy the requirements of one application. Therefore, slight mechanical or electrical variations should not disqualify the nearest equivalent.

The data contained in this guide is believed to be accurate. However, no responsibility is assumed by Texas Instruments Incorporated for the use of this data in actual circuit design.

Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
1N2175		Photodiode	TIL401	D
3N-903†	ENL	Opto-coupler	TIL107	D, E
3N-903-N†	ENL	Opto-coupler	TIL108	D, E
4N25		Opto-coupler	TIL116	A
4N26		Opto-coupler	TIL116	A
4N27		Opto-coupler	TIL116	A
4N28		Opto-coupler	TIL116	A
4N29		Opto-coupler	TIL113	B
4N30		Opto-coupler	TIL113	A
4N31		Opto-coupler	TIL113	A
4N32		Opto-coupler	TIL113	B
4N33		Opto-coupler	TIL113	A
4N34		Opto-coupler	TIL113	A
4N35		Opto-coupler	TIL113	D
4N36		Opto-coupler	TIL113	D
4N37		Opto-coupler	TIL113	B
521-9165	Dialco	Visible Emitter	TIL220	C
521-9166	Dialco	Visible Emitter	TIL220	C
521-9167	Dialco	Visible Emitter	TIL220	C
521-9168	Dialco	Visible Emitter	TIL220	C

†These are the designations of the indicated manufacturer and should not be confused with JEDEC designations.

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Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
521-9180	Dialco	Visible Emitter	TIL220	C
521-9185	Dialco	Visible Emitter	TIL209A	E
521-9186	Dialco	Visible Emitter	TIL209A	E
521-9189	Dialco	Visible Emitter	TIL209A	A
521-9190	Dialco	Visible Emitter	TIL221	C
550-0101	Dialco	Visible Emitter	TIL220	D, E
550-0102	Dialco	Visible Emitter	TIL220	D, E
550-0103	Dialco	Visible Emitter	TIL220	D, E
551-0001	Dialco	Opto-coupler	TIL117	B, E
551-0002	Dialco	Opto-coupler	TIL111	A
551-0003	Dialco	Opto-coupler	TIL112	A
551-0004	Dialco	Opto-coupler	TIL117	B, E
730-0004	Dialco	Visible Numeric Display	TIL321	D, E
730-0005	Dialco	Visible Numeric Display	TIL330	D, E
730-1004	Dialco	Visible Numeric Display	TIL321	D, E
730-1005	Dialco	Visible Numeric Display	TIL330	D, E
745-0005	Dialco	Visible Alphanumeric Display	TIL305	A
745-0006	Dialco	Visible Numeric Display	TIL302	A
745-0007	Dialco	Visible Numeric Display With Logic	TIL311	A
745-0008	Dialco	Visible Numeric Display With Logic	TIL308	A
745-0009	Dialco	Visible Numeric Display With Logic	TIL306	A
5082-4203	Hewlett Packard	Pin Photodiode	TIXL80	B, C
5082-4204	Hewlett Packard	Pin Photodiode	TIXL80	B, C
5082-4205	Hewlett Packard	Pin Photodiode	TIXL80	B, E
5082-4207	Hewlett Packard	Pin Photodiode	TIXL80	B, C
5082-4220	Hewlett Packard	Pin Photodiode	TIXL80	B, C
5082-4403	Hewlett Packard	Visible Emitter	TIL220	C
5082-4415	Hewlett Packard	Visible Emitter	TIL220	C
5082-4420	Hewlett Packard	Visible Emitter	TIL204	B, C
5082-4440	Hewlett Packard	Visible Emitter	TIL220	C
5082-4444	Hewlett Packard	Visible Emitter	TIL220	C
5082-4480	Hewlett Packard	Visible Emitter	TIL209A	C
5082-4483	Hewlett Packard	Visible Emitter	TIL209A	C
5082-4484	Hewlett Packard	Visible Emitter	TIL209A	C
5082-4486	Hewlett Packard	Visible Emitter	TIL209A	C
5082-4850	Hewlett Packard	Visible Emitter	TIL220	C
5082-4880	Hewlett Packard	Visible Emitter	TIL220	C
5082-4881	Hewlett Packard	Visible Emitter	TIL220	C
5082-4882	Hewlett Packard	Visible Emitter	TIL220	C
5082-4883	Hewlett Packard	Visible Emitter	TIL221	C
5082-4884	Hewlett Packard	Visible Emitter	TIL221	C
5082-4885	Hewlett Packard	Visible Emitter	TIL221	C
5082-4886	Hewlett Packard	Visible Emitter	TIL220	C
5082-4887	Hewlett Packard	Visible Emitter	TIL220	C
5082-4888	Hewlett Packard	Visible Emitter	TIL220	C
5082-7000	Hewlett Packard	Visible Numeric Display With Logic	TIL507	D, E
5082-7001	Hewlett Packard	Visible Numeric Display With Logic	TIL560	D, E
5082-7018	Hewlett Packard	Visible ±1 Display With Logic	TIL507	D, E
5082-7100	Hewlett Packard	Visible Alphanumeric Display – 3 Characters	TIL305 (3 REQ'D)	E

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Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
5082-7101	Hewlett Packard	Visible Alphanumeric Display – 4 Characters	TIL305 (4 REQ'D)	E
5082-7102	Hewlett Packard	Visible Alphanumeric Display – 5 Characters	TIL305 (5 REQ'D)	E
5082-7300	Hewlett Packard	Visible Numeric Display With Logic	TIL311	E
5082-7302	Hewlett Packard	Visible Numeric Display With Logic	TIL311	E
5082-7304	Hewlett Packard	Visible ±1 Display	TIL304	E
5082-7340	Hewlett Packard	Visible Numeric Display With Logic	TIL311	E
5082-7402	Hewlett Packard	Visible Numeric Display – 3 Digits	TIL360	E
5082-7403	Hewlett Packard	Visible Numeric Display – 3 Digits	TIL360	E
5082-7404	Hewlett Packard	Visible Numeric Display – 4 Digits	TIL360	E
5082-7405	Hewlett Packard	Visible Numeric Display – 5 Digits	TIL360	E
5082-7412	Hewlett Packard	Visible Numeric Display – 3 Digits	TIL360	E
5082-7413	Hewlett Packard	Visible Numeric Display – 3 Digits	TIL360	E
5082-7414	Hewlett Packard	Visible Numeric Display – 4 Digits	TIL360	E
5082-7415	Hewlett Packard	Visible Numeric Display – 5 Digits	TIL360	E
5082-7730	Hewlett Packard	Visible Numeric Display	TIL312	A
5082-7731	Hewlett Packard	Visible Numeric Display	TIL312	A
5082-7732	Hewlett Packard	Visible Numeric Display	TIL327	A
5082-7740	Hewlett Packard	Visible Numeric Display	TIL313	A
5082-7750	Hewlett Packard	Visible Numeric Display	TIL321	D, E
5082-7751	Hewlett Packard	Visible Numeric Display	TIL321	D, E
40598	RCA	IR Emitter	TIL23	E
40598A	RCA	IR Emitter	TIL24	E
40736R	RCA	IR Emitter	TIL24	E
CLT2010	Clairex	Phototransistor	TIL81	B
CLT2020	Clairex	Phototransistor	TIL81	B
CLT2030	Clairex	Phototransistor	TIL81	B
CLT2130	Clairex	Phototransistor	TIL81	B
CLT2140	Clairex	Phototransistor	TIL81	B
CLT2150	Clairex	Phototransistor	TIL81	B
CLT2160	Clairex	Phototransistor	TIL81	B
CLT3020	Clairex	Phototransistor	TIL605	B
CLT3030	Clairex	Phototransistor	TIL606	B
CLT3160	Clairex	Phototransistor	TIL602	B, C
CLT3170	Clairex	Phototransistor	TIL604	B, C
CLT4020	Clairex	Phototransistor	TIL613	B, C
CLT4030	Clairex	Phototransistor	TIL614	B, C
CLT4160	Clairex	Phototransistor	TIL610	B, C
CLT4170	Clairex	Phototransistor	TIL612	B, C
CM-710	HEI	Phototransistor Card Reader Array, 10-Element	TIL132	D, E
CM3-1RED	Chicago Miniature	Visible Emitter	TIL203	A
CM4-20CLEAR	Chicago Miniature	Visible Emitter	TIL221	C
CM4-21CLEAR	Chicago Miniature	Visible Emitter	TIL220	C
CM4-22RED	Chicago Miniature	Visible Emitter	TIL220	C
CM4-50RED	Chicago Miniature	Visible Emitter	TIL209A	E
CM4-100	Chicago Miniature	Visible Numeric Display	TIL302	A
CM4-101	Chicago Miniature	Visible ± Display	TIL304	A
CM4-110	Chicago Miniature	Visible Numeric Display	TIL302	A

Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI equivalent	Code
CM4-111	Chicago Miniature	Visible ± Display	TIL304	A
CM4-5010	Chicago Miniature	Opto-coupler	TIL112	A
CM4-5020	Chicago Miniature	Opto-coupler	TIL111	A
CM4-23RED	Chicago Miniature	Visible Emitter	TIL220	C
CR-712	HEI	Phototransistor Card Reader Array, 12-Element	TIL135	D, E
DL-1A	Litronix	Visible Numeric Display	TIL302	A
DL-4	Litronix	Visible Numeric Display	TIL302	D, E
DL-6	Litronix	Visible Numeric Display	TIL321	E
DL-8	Litronix	Visible Numeric Display	TIL302	E
DL-10	Litronix	Visible Numeric Display	TIL302	A
DL-10A	Litronix	Visible Numeric Display	TIL302	A
DL-57	Litronix	Visible Alphanumeric Display	TIL305	A
DL-61	Litronix	Visible Numeric Display	TIL330	E
DL-62	Litronix	Visible Numeric Display	TIL321	E
DL-63	Litronix	Visible Numeric Display	TIL330	E
DL-81	Litronix	Visible ± 1 Display	TIL304	E
DL-101	Litronix	Visible ± 1 Display	TIL304	A
DL-101A	Litronix	Visible ± 1 Display	TIL304	A
DL-402	Litronix	Visible Numeric Display	TIL303	D, E
DL-410	Litronix	Visible Numeric Display	TIL302	D, E
DL-411	Litronix	Visible Numeric Display	TIL303	D, E
DL-701	Litronix	Visible ± 1 Display	TIL327	C
DL-704	Litronix	Visible Numeric Display	TIL313	C
DL-707	Litronix	Visible Numeric Display	TIL312	C
DL-707R	Litronix	Visible Numeric Display	TIL312	C
DL-727	Litronix	Visible Numeric Display	TIL361	D, E
DL-746	Litronix	Visible Numeric Display	TIL330	E
DL-747	Litronix	Visible Numeric Display	TIL321	E
DL-747	Xcitron	Visible Numeric Display	TIL321	D, E
DL-750	Litronix	Visible Numeric Display	TIL322	E
DL-1001A	Litronix	Visible ± 1 Display	TIL304	A
E-401W	ENL	IR Emitter	TIL31	B, C
E-473A	ENL	IR Emitter	TIL31	B, C
E-498	ENL	Visible Emitter	TIL204	B, C
ED123	Sprague	Visible Emitter	TIL220	A
ED126	Sprague	Visible Emitter	TIL221	B
ED150	Sprague	Visible Emitter	TIL209A	E
ED154	Sprague	Visible Emitter	TIL331	B
ED155	Sprague	Visible Emitter	TIL209A	E
ED201	Sprague	Visible Numeric Display	TIL302	A
ED203	Sprague	Visible Numeric Display	TIL310	E
ED213	Sprague	Visible Numeric Display	TIL310	E
ED360	Sprague	IR Emitter	TIL32	E
ED401	Sprague	Phototransistor	TIL81	C
ED702	Sprague	Opto-coupler	TIL111	B
ED730	Sprague	Opto-coupler	TIL113	A
EPY68	European Electronic Prod	Photodiode	TIL401	C, D
FCD810	Fairchild	Opto-coupler	TIL116	B

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Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
FCD811	Fairchild	Opto-coupler	TIL116	B
FCD820	Fairchild	Opto-coupler	TIL116	B
FLV100	Fairchild	Visible Emitter	TIL221	E
FLV101	Fairchild	Visible Emitter	TIL220	E
FLV102	Fairchild	Visible Emitter	TIL220	E
FLV103	Fairchild	Visible Emitter	TIL220	E
FLV104	Fairchild	Visible Emitter	TIL221	D, E
FLV107	Fairchild	Visible Emitter	TIL206	D, E
FLV108	Fairchild	Visible Emitter	TIL220	E
FLV110	Fairchild	Visible Emitter	TIL220	C
FLV111	Fairchild	Visible Emitter	TIL221	C
FLV112	Fairchild	Visible Emitter	TIL220	C
FLV114	Fairchild	Visible Emitter	TIL221	E
FLV115	Fairchild	Visible Emitter	TIL220	E
FLV116	Fairchild	Visible Emitter	TIL220	E
FLV117	Fairchild	Visible Emitter	TIL220	C
FLV118	Fairchild	Visible Emitter	TIL221	C
FLV119	Fairchild	Visible Emitter	TIL220	C
FNA21	Fairchild	Visible Numeric Display – 6 Digits	TIL360	E
FNA25	Fairchild	Visible Numeric Display –9 Digits	TIL360 (2 REQ'D)	E
FNA30	Fairchild	Visible Numeric Display – 9 Digits	TIL360 (2 REQ'D)	E
FNA45	Fairchild	Visible Numeric Display – 9 Digits	TIL360 (2 REQ'D)	E
FND70	Fairchild	Visible Numeric Display	TIL302	E
FND71	Fairchild	Visible Numeric Display	TIL327	D, E
FND357	Fairchild	Visible Numeric Display	TIL313	B, C
FND500	Fairchild	Visible Numeric Display	TIL322	C
FND507	Fairchild	Visible Numeric Display	TIL321	C
FPA100	Fairchild	9-Channel Source/Sensor Assy	TIL133	E
FPA101	Fairchild	12-Channel Source/Sensor Assy	TIL136	E
FPA102	Fairchild	10-Channel Source/Sensor Assy	TIL141	D, E
FPA103	Fairchild	1-Channel Source/Sensor Reflective Assembly	TIL139	E
FPA104	Fairchild	1-Channel Source/Sensor Reflective Assembly	TIL139	E
FPA105	Fairchild	1-Channel Source/Sensor Reflective Assembly	TIL139	E
FPA700	Fairchild	9-Element Phototransistor Array	TIL132	E
FPA700A	Fairchild	9-Element Phototransisotr Array	TIL132	E
FPA710	Fairchild	12-Element Phototransistor Array	TIL135	E
FPA710A	Fairchild	12-Element Phototransistor Array	TIL135	E
FPA720	Fairchild	10-Element Phototransistor Array	TIL132 or TIL135	D, E
FPA720A	Fairchild	10-Element Phototransistor Array	TIL132 or TIL135	D, E
FPE100	Fairchild	IR Emitter	TIL32	B, C
FPE104	Fairchild	IR Emitter	TIL32	D, E
FPT100	Fairchild	Phototransistor	TIL65	B, C
FPT100A	Fairchild	Phototransistor	TIL66	B, C
FPT100B	Fairchild	Phototransistor	TIL66	B, C
FPT101	Fairchild	Phototransistor	TIL613	B, C
FPT102	Fairchild	Photodiode	TIL81	B
FPT110	Fairchild	Phototransistor	TIL65	B, C

Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
FPT110A	Fairchild	Phototransistor	TIL66	B, C
FPT110B	Fairchild	Phototransistor	TIL66	B, C
FPT120	Fairchild	Phototransistor	TIL67	B, C
FPT120A	Fairchild	Phototransistor	TIL67	B, C
FPT120B	Fairchild	Phototransistor	TIL67	B, C
FPT130	Fairchild	Phototransistor	TIL67	B, C
FPT130A	Fairchild	Phototransistor	TIL66	B, C
FPT130B	Fairchild	Phototransistor	TIL66	B, C
FPT131	Fairchild	Phototransistor	TIL63	B, C
FPT132	Fairchild	Phototransistor	TIL67	B, C
FPT136	Fairchild	Phototransistor	TIL63	B, C
FPT137	Fairchild	Phototransistor	TIL67	B, C
FPT220	Fairchild	Phototransistor	TIL67	B, C
FPT230	Fairchild	Phototransistor	TIL67	B, C
FPT320	Fairchild	Phototransistor	TIL67	B, C
FPT330	Fairchild	Phototransistor	TIL67	B, C
GS-100	General Sensor	Phototransistor	TIL606	C
GS-300	General Sensor	Phototransistor	LS400	C
GS-400	General Sensor	Phototransistor	LS400	A
GS-403	General Sensor	Phototransistor	LS400	B
GS-420	General Sensor	Phototransistor	LS400	A
GS-422	General Sensor	Phototransistor	LS400	B
GS-423	General Sensor	Phototransistor	LS400	B
GS-470	General Sensor	Phototransistor	LS400	B
GS-600	General Sensor	Phototransistor	TIL81	B, C
GS-603	General Sensor	Phototransistor	TIL81	B, C
GS-606	General Sensor	Phototransistor	TIL81	B, C
GS-609	General Sensor	Phototransistor	TIL81	B, C
GS-610	General Sensor	Phototransistor	TIL81	B, C
GS-612	General Sensor	Phototransistor	TIL81	B, C
GS-670	General Sensor	Phototransistor	TIL81	B, C
GS-680	General Sensor	Phototransistor	TIL81	B, C
GS-683	General Sensor	Phototransistor	TIL81	B, C
GS-686	General Sensor	Phototransistor	TIL81	B, C
H10A1	GE	Opto-coupler	TIL102	B, C
H10B1	GE	Opto-coupler	TIL103	B, C
H11A1	GE	Opto-coupler	TIL117	B
H11A2	GE	Opto-coupler	TIL116	B
H11A3	GE	Opto-coupler	TIL116	B
H11A4	GE	Opto-coupler	TIL112	B
H11A5	GE	Opto-coupler	TIL111	B
H11B1	GE	Opto-coupler	TIL113	B
H11B2	GE	Opto-coupler	TIL113	B
H13A1	GE	1-Channel Source/Sensor Transmissive Assembly	TIL138	C
H13A2	GE	1-Channel Source/Sensor Transmissive Assembly	TIL138	C
H13B1	GE	1-Channel Source/Sensor Transmissive Assembly	TIL138	B, C

Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
H13B2	GE	1-Channel Source/Sensor Transmissive Assembly	TIL138	B, C
H15A1	GE	Opto-coupler	TIL109	D, E
H15A2	GE	Opto-coupler	TIL109	D, E
H15B1	GE	Opto-coupler	TIL109	D, E
H15B2	GE	Opto-coupler	TIL109	D, E
HLS400	Hutson	Phototransistor	LS400	A
HT700	HEI	Phototransistor	TIL78	D, E
IL-1	Litronix	Opto-coupler	TIL116	B
IL-5	Litronix	Opto-coupler	TIL117	B
IL-12	Litronix	Opto-coupler	TIL112	B
IL-15	Litronix	Opto-coupler	TIL112	B
IL-16	Litronix	Opto-coupler	TIL112	B
IL-74	Litronix	Opto-coupler	TIL111	B
ILCA-2-30	Litronix	Opto-coupler	TIL113	B
IRL-40	Litronix	IR Emitter	TIL26	D, E
IRL-60	Litronix	IR Emitter	TIL32	E
L14A502	GE	Phototransistor	TIL81	C
L14C1	GE	Phototransistor	TIL81	C
L14E1	GE	Phototransistor	TIL78	E
L14E2	GE	Phototransistor	TIL78	E
L14E3	GE	Phototransistor	TIL78	E
L14E4	GE	Phototransistor	TIL78	E
L14G1	GE	Phototransistor	TIL81	C
L14G2	GE	Phototransistor	TIL81	C
L15A600	GE	Phototransistor	TIL600	A
L15AX601	GE	Phototransistor	TIL601	A
L15AX602	GE	Phototransistor	TIL602	A
L15AX603	GE	Phototransistor	TIL603	A
L15AX604	GE	Phototransistor	TIL604	A
L15E	GE	Phototransistor	TIL81	E
L15E1	GE	Phototransistor	TIL81	E
L15E2	GE	Phototransistor	TIL81	E
L15E3	GE	Phototransistor	TIL81	E
L15E4	GE	Phototransistor	TIL81	E
LA-09	HEI	Phototransistor Tape Reader Array, 9-Element	TIL132	D, E
LA-600	HEI	Phototransistor	TIL601	B, C
LA-609-X-X	HEI	Phototransistor Tape Reader Array, 9-Element	TIL132	D, E
LA-700	HEI	Phototransistor	TIL601	D, E
LEA-400	HEI	IR Emitter	TIL23	D, E
LEA-409-X-X	HEI	IR Emitter Tape Reader Array, 9-Element	TIL131	D, E
LEA-500	HEI	IR Emitter	TIL23	D, E
MA2201R	MIL	Visible Emitter	TIL221	D, E
MA2202R	MIL	Visible Emitter	TIL221	D, E
MA2301R	MIL	Visible Emitter	TIL221	D, E
MA2302R	MIL	Visible Emitter	TIL221	D, E
MA2401R	MIL	Visible Emitter	TIL221	C, D

Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
MA2402R	MIL	Visible Emitter	TIL221	C, D
MA2403R	MIL	Visible Emitter	TIL220	C, D
MA2404R	MIL	Visible Emitter	TIL220	C, D
MA2501R	MIL	Visible Emitter	TIL221	D, E
MA2502R	MIL	Visible Emitter	TIL221	D, E
MA2503R	MIL	Visible Emitter	TIL220	D, E
MA2504R	MIL	Visible Emitter	TIL220	D, E
MAN1	Monsanto	Visible Numeric Display	TIL302	A
MAN1A	Monsanto	Visible Numeric Display	TIL302	A
MAN1B	Monsanto	Visible Numeric Display	TIL302	B
MAN1BA	Monsanto	Visible Numeric Display	TIL302	B
MAN2	Monsanto	Visible Alphanumeric Display	TIL305	A
MAN2A	Monsanto	Visible Alphanumeric Display	TIL305	A
MAN4	Monsanto	Visible Numeric Display	TIL302	D, E
MAN5	Monsanto	Visible Numeric Display	TIL314	B, C
MAN6A	Monsanto	Visible Numeric Display	TIL321	E
MAN7	Monsanto	Visible Numeric Display	TIL302	E
MAN8	Monsanto	Visible Numeric Display	TIL314	B, C
MAN10	Monsanto	Visible Numeric Display	TIL302	A
MAN10A	Monsanto	Visible Numeric Display	TIL302	A
MAN51	Monsanto	Visible Numeric Display	TIL314	C
MAN52	Monsanto	Visible Numeric Display	TIL314	C
MAN53	Monsanto	Visible Numeric Display	TIL328	C
MAN54	Monsanto	Visible Numeric Display	TIL315	C
MAN64A	Monsanto	Visible Numeric Display	TIL321	E
MAN66A	Monsanto	Visible Numeric Display	TIL321	E
MAN71	Monsanto	Visible Numeric Display	TIL312	C
MAN72	Monsanto	Visible Numeric Display	TIL312	C
MAN73	Monsanto	Visible Numeric Display	TIL327	C
MAN74	Monsanto	Visible Numeric Display	TIL313	C
MAN81	Monsanto	Visible Numeric Display	TIL315	C
MAN82	Monsanto	Visible Numeric Display	TIL315	C
MAN83	Monsanto	Visible Numeric Display	TIL329	C
MAN84	Monsanto	Visible Numeric Display	TIL316	C
MAN101	Monsanto	Visible ± 1 Display	TIL304	A
MAN101A	Monsanto	Visible ± 1 Display	TIL304	A
MAN601A	Monsanto	Visible Numeric Display	TIL330	E
MAN641A	Monsanto	Visible Numeric Display	TIL330	E
MAN661A	Monsanto	Visible Numeric Display	TIL330	E
MAN1001	Monsanto	Visible ± 1 Display	TIL304	A
MAN1001A	Monsanto	Visible ± 1 Display	TIL304	A
MAN1002	Monsanto	Visible Numeric Display	TIL311	D, E
MAN1002A	Monsanto	Visible Numeric Display	TIL311	D, E
MAN4001	Monsanto	Visible ± 1 Display	TIL304	D, E
MAN7001	Monsanto	Visible ± Display	TIL304	E
MCA2-30	Monsanto	Opto-coupler	TIL113	B
MCA7	Monsanto	1-Channel Source/Sensor Reflective Assembly	TIL139	B, C
MCA8	Monsanto	1-Channel Source/Sensor Transmissive Assembly	TIL145	A

Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
MCA81	Monsanto	1-Channel Source/Sensor Transmissive Assembly	TIL146	A
MCA231	Monsanto	Opto-coupler	TIL113	B, C
MCD2	Monsanto	Opto-coupler	TIL111	B, C
MCD2-M	Monsanto	Opto-coupler	TIL111	B, C
MCD4	Monsanto	Opto-coupler	TIL102	C
MCT2	Monsanto	Opto-coupler	TIL116	B
MCT2E	Monsanto	Opto-coupler	TIL116	B
MCT2F	Monsanto	Opto-coupler	TIL114	B
MCT4	Monsanto	Opto-coupler	TIL120	B
MCT8	Monsanto	Opto-coupler	TIL143	A
MCT26	Monsanto	Opto-coupler	TIL112	B
MCT81	Monsanto	Opto-coupler	TIL144	A
MCT230	Monsanto	Opto-coupler	TIL116	D
MCT510	Monsanto	Opto-coupler	TIL108	B, C
MDA6101	Monsanto	Visible Numeric Display With Logic	TIL308	E
MDA6102A	Monsanto	Visible Numeric Display With Logic	TIL308	E
MDA6102B	Monsanto	Visible Numeric Display With Logic	TIL306	D, E
MDA6103	Monsanto	Visible Numeric Display With Logic	TIL306	D, E
MDA6141	Monsanto	Visible Numeric Display With Logic	TIL311	D, E
ME2	Monsanto	IR Emitter	TIXL27	C
ME2A	Monsanto	IR Emitter	TIXL27	C
ME3	Monsanto	IR Emitter	TIL23	E
ME4	Monsanto	IR Emitter	TIL26	B, E
ME5	Monsanto	IR Emitter	TIXL27	A
ME5A	Monsanto	IR Emitter	TIXL27	A
ME60	Monsanto	IR Emitter	TIL32	E
ME61	Monsanto	IR Emitter	TIL32	E
ME7021	Monsanto	IR Emitter	TIL31	E
ME7022	Monsanto	IR Emitter	TIL31	E
ME7023	Monsanto	IR Emitter	TIL31	E
ME7024	Monsanto	IR Emitter	TIL31	E
MI20C	Monsanto	IR Emitter	TIL26	B, E
MLED50	Motorola	Visible Emitter	TIL209A	E
MLED55	Motorola	Visible Emitter	TIL209A	E
MLED60	Motorola	IR Emitter	TIL32	E
MLED90	Motorola	IR Emitter	TIL32	E
MLED92	Motorola	IR Emitter	TIL32	E
MLED455	Motorola	Visible Emitter	TIL209A	B, C
MLED500	Motorola	Visible Emitter	TIL209A	E
MLED600	Motorola	Visible Emitter	TIL209A	E
MLED610	Motorola	Visible Emitter	TIL206	E
MLED630	Motorola	Visible Emitter	TIL203	A
MLED640	Motorola	Visible Emitter	TIL220	B, C
MLED650	Motorola	Visible Emitter	TIL220	A
MLED655	Motorola	Visible Emitter	TIL220	A
MLED660	Motorola	Visible Emitter	TIL220	B, C
MLED665	Motorola	Visible Emitter	TIL221	B, C
MLED900	Motorola	IR Emitter	TIL32	E
MLED910	Motorola	IR Emitter	TIL23	A

Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
MLED930	Motorola	IR Emitter	TIL31	A
MOC1000	Motorola	Opto-coupler	TIL116	A
MOC1001	Motorola	Opto-coupler	TIL116	A
MOC1002	Motorola	Opto-coupler	TIL116	A
MOC1003	Motorola	Opto-coupler	TIL136	A
MOC1100	Motorola	Opto-coupler	TIL113	A
MOC1200	Motorola	Opto-coupler	TIL113	A
MOC2000	Motorola	Opto-coupler	TIL107	B
MOC2200	Motorola	Opto-coupler	TIL108	B, C
MRD150	Motorola	Phototransistor	TIL78	E
MRD300	Motorola	Phototransistor	TIL81	B, C
MRD310	Motorola	Phototransistor	TIL81	B, C
MRD450	Motorola	Phototransistor	TIL78	E
MRD500	Motorola	Pin Photodiode	TIXL80	D, E
MRD510	Motorola	Pin Photodiode	TIXL80	D, E
MRD601	Motorola	Phototransistor	TIL601	A
MRD602	Motorola	Phototransistor	TIL602	A
MRD603	Motorola	Phototransistor	TIL603	A
MRD604	Motorola	Phototransistor	TIL604	A
MRD810	Motorola	Phototransistor	TIL81	B, C
MRD3050	Motorola	Phototransistor	TIL81	B, C
MRD3051	Motorola	Phototransistor	TIL81	B, C
MRD3052	Motorola	Phototransistor	TIL81	B, C
MRD3053	Motorola	Phototransistor	TIL81	B, C
MRD3054	Motorola	Phototransistor	TIL81	B, C
MRD3055	Motorola	Phototransistor	TIL81	B, C
MRD3056	Motorola	Phototransistor	TIL81	B, C
MT1	Monsanto	Phototransistor	TIL81	C
MT2	Monsanto	Phototransistor	TIL81	C
MV4	Monsanto	Visible Emitter	TIL220	D, E
MV4H	Monsanto	Visible Emitter	TIL220	D, E
MV10B	Monsanto	Visible Emitter	TIL203	A
MV10C	Monsanto	Visible Emitter	TIL203	C
MV50	Monsanto	Visible Emitter	TIL209A	E
MV54	Monsanto	Visible Emitter	TIL209A	E
MV55	Monsanto	Visible Emitter	TIL209A	E
MV5010	Monsanto	Visible Emitter	TIL221	C
MV5011	Monsanto	Visible Emitter	TIL220	C
MV5012	Monsanto	Visible Emitter	TIL221	B, C
MV5013	Monsanto	Visible Emitter	TIL220	C
MV5020	Monsanto	Visible Emitter	TIL221	A
MV5021	Monsanto	Visible Emitter	TIL220	A
MV5022	Monsanto	Visible Emitter	TIL221	B
MV5023	Monsanto	Visible Emitter	TIL220	A
MV5024	Monsanto	Visible Emitter	TIL220	A
MV5025	Monsanto	Visible Emitter	TIL220	A
MV5026	Monsanto	Visible Emitter	TIL220	A
MV5030	Monsanto	Visible Emitter	TIL221	C
MV5033	Monsanto	Visible Emitter	TIL220	C
MV5053	Monsanto	Visible Emitter	TIL220	D

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Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
MV5054-1	Monsanto	Visible Emitter	TIL221	B
MV5054-2	Monsanto	Visible Emitter	TIL221	B
MV5054-3	Monsanto	Visible Emitter	TIL220	B
MV5055	Monsanto	Visible Emitter	TIL220	D
MV5056	Monsanto	Visible Emitter	TIL220	D
MV5063	Monsanto	Visible Emitter	TIL209A	D
MV5074	Monsanto	Visible Emitter	TIL209A	C
MV5080	Monsanto	Visible Emitter	TIL209A	E
MV5082	Monsanto	Visible Emitter	TIL209A	E
NDP-1	OPCOA	Visible Numeric Display	TIL312	C
NDP-11	OPCOA	Visible Numeric Display	TIL314	C
NDP-21	OPCOA	Visible Numeric Display	TIL316	C
NSL000	National	Visible Emitter	TIL221	B, C
NSL002	National	Visible Emitter	TIL220	B, C
NSL100	National	Visible Emitter	TIL221	B, C
NSL101	National	Visible Emitter	TIL220	B, C
NSL102	National	Visible Emitter	TIL220	B, C
NSL610	National	Phototransistor	TIL81	B
NSL5020	National	Visible Emitter	TIL221	A
NSL5022	National	Visible Emitter	TIL221	B
NSL5023	National	Visible Emitter	TIL220	B
NSL5024	National	Visible Emitter	TIL220	B
NSL5026	National	Visible Emitter	TIL220	B
NSL5027	National	Visible Emitter	TIL221	B, C
NSN33	National	Visible Numeric Display — 3 Digits	TIL360	D, E
OP122	Optron	IR Emitter	TIL23	A
OP123	Optron	IR Emitter	TIL23	A
OP124	Optron	IR Emitter	TIL24	A
OP131	Optron	IR Emitter	TIL31	A
OP150	Optron	IR Emitter		
OP400	Optron	Phototransistor	LS400	A
OP440	Optron	Phototransistor	LS400	A
OP600	Optron	Phototransistor	LS600	A
OP601	Optron	Phototransistor	TIL601	A
OP602	Optron	Phototransistor	TIL602	A
OP603	Optron	Phototransistor	TIL603	A
OP604	Optron	Phototransistor	TIL604	A
OP605	Optron	Phototransistor	TIL604	B
OP640	Optron	Phototransistor	LS600	A
OP641	Optron	Phototransistor	TIL601	A
OP642	Optron	Phototransistor	TIL602	A
OP643	Optron	Phototransistor	TIL603	A
OP644	Optron	Phototransistor	TIL604	A
OP645	Optron	Phototransistor	TIL604	B
OP700	Optron	Phototransistor	TIL613	B
OP701	Optron	Phototransistor	TIL613	B
OP702	Optron	Phototransistor	TIL613	B
OP703	Optron	Phototransistor	TIL614	B
OP704	Optron	Phototransistor	TIL614	B
OP705	Optron	Phototransistor	TIL616	B

Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
OP750	Optron	Phototransistor		
OP790	Optron	Photodiode	TIL81	D, E
OP800	Optron	Phototransistor	TIL81	A
OP801	Optron	Phototransistor	TIL81	A
OP802	Optron	Phototransistor	TIL81	A
OP803	Optron	Phototransistor	TIL81	A
OP804	Optron	Phototransistor	TIL81	A
OP805	Optron	Phototransistor	TIL81	B
OP900	Optron	Photodiode	TIL81	D, E
OP1030	Optron	Opto-coupler	TIL109	B, C
OP1031	Optron	Opto-coupler	TIL109	B, C
OP1050-5	Optron	Opto-coupler	TIL109	D, E
OP1050-10	Optron	Opto-coupler	TIL109 SPECIAL	B, C
OP1052-5	Optron	Opto-coupler	TIL109	D, E
OP1053-5	Optron	Opto-coupler	TIL109	D, E
OP1053-10	Optron	Opto-coupler	TIL109 SPECIAL	B, C
OP1056-10	Optron	Opto-coupler	TIL109 SPECIAL	B, C
OP1060	Optron	Opto-coupler	TIL109	B, C
OP1061	Optron	Opto-coupler	TIL109	B, C
OP1090	Optron	Opto-coupler	TIL109	B, C
OPA505	Optron	Phototransistor Array – 6-Element	TIL133	B, C
OPA508	Optron	Phototransistor Tape Reader Array, 9-Element	TIL132	B, C
OPA512	Optron	Phototransistor Card Reader Array, 12-Element	TIL135	B, C
OPA518	Optron	Phototransistor Array – 18-Element	CUSTOM	A
OPB120	Optron	Source-Detector Assembly, 1-Channel	TIL138	B, C
OPB121	Optron	Source-Detector Assembly, 1-Channel	TIL138	B, C
OPB125	Optron	Source-Detector Assembly, 1-Channel	TIL139	B, C
OPB243	Optron	Source-Detector Assembly, 1-Channel	TIL138	B, C
OPB253	Optron	Source-Detector Assembly, 1-Channel	TIL139	B, C
OPB505	Optron	Source-Detector Array – 6-Channel	TIL133	B, C
OPB508	Optron	Source-Detector Array – 9-Channel	TIL133	B, C
OPB512	Optron	Source-Detector Array – 12-Channel	TIL136	B, C
OPB518	Optron	Source-Detector Array – 18-Channel	CUSTOM	A
OPE505	Optron	IR Emitter Array – 6-Element	TIL131	B, C
OPE508	Optron	IR Emitter Tape Reader Array, 9-Element	TIL131	B, C
OPE512	Optron	IR Emitter Card Reader Array, 12-Element	TIL134	B, C
OPE518	Optron	IR Emitter Array – 18-Element	CUSTOM	A
OS-521 SERIES	HEI	1-Channel Source/Sensor Transmissive Assembly	TIL138	D, E
OS-581 SERIES	HEI	1-Channel Source/Sensor Transmissive Assembly	TIL138	D, E
OSL-1	OPCOA	Visible Emitter	TIL206	C, D
OSL-2	OPCOA	Visible Emitter	TIL206	D, E
OSL-3	OPCOA	Visible Emitter	TIL220	B, C
OSL-3-1	OPCOA	Visible Emitter	TIL221	B, C
OSL-3-2	OPCOA	Visible Emitter	TIL220	B, C
OSL-3-3	OPCOA	Visible Emitter	TIL221	B, C

Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
OSL-3L	OPCOA	Visible Emitter	TIL220	B, C
OSL-3L-1	OPCOA	Visible Emitter	TIL221	B, C
OSL-3L-2	OPCOA	Visible Emitter	TIL220	B, C
OSL-3L-3	OPCOA	Visible Emitter	TIL221	B, C
OSL-5	OPCOA	Visible Emitter	TIL209A	D, E
OSL-6	OPCOA	Visible Emitter	TIL220	B, C
OSL-6-1	OPCOA	Visible Emitter	TIL221	B, C
OSL-6-2	OPCOA	Visible Emitter	TIL220	B, C
OSL-6-3	OPCOA	Visible Emitter	TIL221	B, C
OSL-6L	OPCOA	Visible Emitter	TIL220	B, C
OSL-6L-1	OPCOA	Visible Emitter	TIL221	B, C
OSL-6L-2	OPCOA	Visible Emitter	TIL220	B, C
OSL-6L-3	OPCOA	Visible Emitter	TIL221	B, C
OSL-50	OPCOA	Visible Emitter	TIL205	D
PC4-73	GE	Opto-coupler	TIL113	E
PC15-26	GE	Opto-coupler	TIL108	E
PMO-2	OPCOA	Visible Numeric Display	TIL327	C
PMO-12	OPCOA	Visible Numeric Display	TIL328	C
PMO-22	OPCOA	Visible Numeric Display	TIL329	C
PT-904L	ENL	Phototransistor	TIL81	B, C
PT-916L	ENL	Phototransistor	TIL81	B, C
PT-916W	ENL	Phototransistor	TIL81	D
QS-100	Quantum Sensing	Phototransistor	TIL63	C
QS-101	Quantum Sensing	Phototransistor	TIL64	C
QS-102	Quantum Sensing	Phototransistor	TIL65	C
QS-103	Quantum Sensing	Phototransistor	TIL66	C
QS-104	Quantum Sensing	Phototransistor	TIL67	C
QS-105	Quantum Sensing	Phototransistor	TIL64	C
QS-106	Quantum Sensing	Phototransistor	TIL67	C
QS-107	Quantum Sensing	Phototransistor	TIL65	C
QS-200	Quantum Sensing	Phototransistor	TIL614	C
QS-201	Quantum Sensing	Phototransistor	TIL615	C
QS-202	Quantum Sensing	Phototransistor	TIL613	C
QS-203	Quantum Sensing	Phototransistor	TIL615	C
QS-204	Quantum Sensing	Phototransistor	TIL614	A
QS-205	Quantum Sensing	Phototransistor	TIL615	A
QS-230	Quantum Sensing	Phototransistor	TIL614	A
QS-300	Quantum Sensing	Phototransistor	TIL81	D
QS-301	Quantum Sensing	Phototransistor	TIL81	D
QS-302	Quantum Sensing	Phototransistor	TIL81	D
QS-303	Quantum Sensing	Phototransistor	TIL81	D
QS-304	Quantum Sensing	Phototransistor	TIL81	D
QS-305	Quantum Sensing	Phototransistor	TIL81	D
QS-400	Quantum Sensing	Phototransistor	LS400	A
QS-401	Quantum Sensing	Phototransistor	LS400	B
QS-402	Quantum Sensing	Phototransistor	LS400	B
QS-403	Quantum Sensing	Phototransistor	LS400	B
QS-404	Quantum Sensing	Phototransistor	LS400	A
QS-600	Quantum Sensing	Phototransistor	LS600	A
QS-601	Quantum Sensing	Phototransistor	TIL601	A

Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
QS-602	Quantum Sensing	Phototransistor	TIL602	A
QS-603	Quantum Sensing	Phototransistor	TIL603	A
QS-604	Quantum Sensing	Phototransistor	TIL604	A
QS-605	Quantum Sensing	Phototransistor	TIL604	A
QS-606	Quantum Sensing	Phototransistor	TIL604	B
QS-3600	Quantum Sensing	Phototransistor Tape Reader Array, 9-Element	TIL132	D, E
QS-8014	Quantum Sensing	Phototransistor Card Reader Assembly, 12-Element	TIL135	D, E
QSL-1	Quantum Sensing	Photodiode	TIL401	D
QSL-11	Quantum Sensing	Photodiode	TIL401	D
QSL-35	Quantum Sensing	Photodiode	TIL401	D
QSL-38	Quantum Sensing	Photodiode	TIL401	D
QSL-60	Quantum Sensing	Photodiode	TIL401	D
QSL-61	Quantum Sensing	Photodiode	TIL401	D
QSL-62	Quantum Sensing	Photodiode	TIL401	D
RL-2	Litronix	Visible Emitter	TIL220	C
RL-2-02	Litronix	Visible Emitter	TIL220	C
RL-2-03	Litronix	Visible Emitter	TIL220	C
RL-2-04	Litronix	Visible Emitter	TIL221	C
RL-4	Litronix	Visible Emitter	TIL203	B
RL-4-02	Litronix	Visible Emitter	TIL204	B
RL-4-05	Litronix	Visible Emitter	TIL203	A
RL-5	Litronix	Visible Emitter	TIL205	A
RL-7	Litronix	Visible Emitter	TIL203	B
RL-7-01	Litronix	Visible Emitter	TIL204	B
RL-20	Litronix	Visible Emitter	TIL220	C
RL-20-02	Litronix	Visible Emitter	TIL221	C
RL-20-03	Litronix	Visible Emitter	TIL220	C
RL-20-04	Litronix	Visible Emitter	TIL221	C
RL-21	Litronix	Visible Emitter	TIL220	C
RL-21-02	Litronix	Visible Emitter	TIL221	C
RL-21-04	Litronix	Visible Emitter	TIL221	C
RL-50	Litronix	Visible Emitter	TIL209A	E
RL-50-01	Litronix	Visible Emitter	TIL209A	E
RL-50-02	Litronix	Visible Emitter	TIL209A	E
RL-50-03	Litronix	Visible Emitter	TIL209A	E
RL-54	Litronix	Visible Emitter	TIL209A	E
RL-209	Litronix	Visible Emitter	TIL209A	A
RL-209-02	Litronix	Visible Emitter	TIL209A	A
RL-209-03	Litronix	Visible Emitter	TIL209A	A
RL-209-04	Litronix	Visible Emitter	TIL209A	A
RL-4403	Litronix	Visible Emitter	TIL220	C
RL-4440	Litronix	Visible Emitter	TIL220	C
RL-4484	Litronix	Visible Emitter	TIL209A	C
RL-4850	Litronix	Visible Emitter	TIL220	C
RL-5054-1	Litronix	Visible Emitter	TIL220	B
RL-5054-2	Litronix	Visible Emitter	TIL220	B
RL-T1	Litronix	Visible Emitter	TIL209A	C
RL-T1-02	Litronix	Visible Emitter	TIL209A	C

Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
RL-T1-03	Litronix	Visible Emitter	TIL209A	C
RL-T1-04	Litronix	Visible Emitter	TIL209A	C
R7M-192-X	Bowmar	Visible Numeric Display	TIL360	C
SC-1481-1	Spectronics	Opto-coupler	TIL113	D, E
SC-1481-2	Spectronics	Opto-coupler	TIL113	D, E
SC-1481-3	Spectronics	Opto-coupler	TIL113	D, E
SC-1482-1	Spectronics	Opto-coupler	TIL109	D, E
SC-1482-2	Spectronics	Opto-coupler	TIL109	D, E
SC-1482-3	Spectronics	Opto-coupler	TIL109	D, E
SC-1484-1	Spectronics	Opto-coupler	TIL107	D, E
SC-1484-2	Spectronics	Opto-coupler	TIL108	D, E
SC-1484-3	Spectronics	Opto-coupler	TIL108	D, E
SD-1420-1	Spectronics	Photodiode	TIL81	D, E
SD-1420-2	Spectronics	Photodiode	TIL81	D, E
SD-1440-1	Spectronics	Phototransistor	TIL610	B, C
SD-1440-2	Spectronics	Phototransistor	TIL611	B, C
SD-1440-3	Spectronics	Phototransistor	TIL612	B, C
SD-1440-4	Spectronics	Phototransistor	TIL612	B, C
SD-1441-1	Spectronics	Phototransistor	TIL613	C
SD-1441-2	Spectronics	Phototransistor	TIL614	C
SD-1441-3	Spectronics	Phototransistor	TIL615	C
SD-2420-1	Spectronics	Photodiode	TIL81	D, E
SD-2420-2	Spectronics	Photodiode	TIL81	D, E
SD-2440-1	Spectronics	Phototransistor	TIL601	A
SD-2440-2	Spectronics	Phototransistor	TIL602	A
SD-2440-3	Spectronics	Phototransistor	TIL603	A
SD-2440-4	Spectronics	Phototransistor	TIL604	A
SD-2441-1	Spectronics	Phototransistor	TIL603	C
SD-2441-2	Spectronics	Phototransistor	TIL604	C
SD-2441-3	Spectronics	Phototransistor	TIL604	C
SD-2441-4	Spectronics	Phototransistor	TIL604	B, C
SD-3420-1	Spectronics	Photodiode	TIL81	B, C
SD-3420-2	Spectronics	Photodiode	TIL81	B, C
SD-3440-1	Spectronics	Phototransistor	TIL81	B, C
SD-3440-2	Spectronics	Phototransistor	TIL81	B, C
SD-3440-3	Spectronics	Phototransistor	TIL81	B, C
SD-3440-4	Spectronics	Phototransistor	TIL81	B, C
SD-3442-1	Spectronics	Phototransistor	TIL81	B, C
SD-3442-2	Spectronics	Phototransistor	TIL81	B, C
SD-3442-3	Spectronics	Phototransistor	TIL81	B, C
SD-5420-1	Spectronics	Photodiode	TIL81	B, C
SD-5420-2	Spectronics	Photodiode	TIL81	B, C
SD-5421-1	Spectronics	Photodiode	TIL81	B, C
SD-5421-2	Spectronics	Photodiode	TIL81	B
SD-5422-2	Spectronics	Photodiode	TIL81	B, C
SD-5440-1	Spectronics	Phototransistor	TIL81	B, C
SD-5440-2	Spectronics	Phototransistor	TIL81	B, C
SD-5440-3	Spectronics	Phototransistor	TIL81	B, C
SD-5440-4	Spectronics	Phototransistor	TIL81	B, C
SD-5442-1	Spectronics	Phototransistor	TIL81	B, C

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Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
SD-5442-2	Spectronics	Phototransistor	TIL81	B, C
SD-5442-3	Spectronics	Phototransistor	TIL81	B, C
SE-1450-1	Spectronics	IR Emitter	TIL23	E
SE-1450-2	Spectronics	IR Emitter	TIL23	E
SE-1450-3	Spectronics	IR Emitter	TIL23	E
SE-1450-4	Spectronics	IR Emitter	TIL24	E
SE-2430-1	Spectronics	IR Emitter	TIL31	E
SE-2430-2	Spectronics	IR Emitter	TIL31	E
SE-2430-3	Spectronics	IR Emitter	TIL31	E
SE-2430-4	Spectronics	IR Emitter	TIL31	E
SE-2450-1	Spectronics	IR Emitter	TIL23	A
SE-2450-2	Spectronics	IR Emitter	TIL23	A
SE-2450-3	Spectronics	IR Emitter	TIL23	A
SE-2460-1	Spectronics	IR Emitter	TIL23	A
SE-2460-2	Spectronics	IR Emitter	TIL23	A
SE-2460-3	Spectronics	IR Emitter	TIL24	A
SE-2460-4	Spectronics	IR Emitter	TIL24	A
SE-3450-1	Spectronics	IR Emitter	TIL31	C
SE-3450-2	Spectronics	IR Emitter	TIL31	C
SE-3450-3	Spectronics	IR Emitter	TIL31	C
SE-3451-1	Spectronics	IR Emitter	TIL31	C
SE-3451-2	Spectronics	IR Emitter	TIL31	C
SE-3451-3	Spectronics	IR Emitter	TIL31	C
SE-5450-1	Spectronics	IR Emitter	TIL31	A
SE-5450-2	Spectronics	IR Emitter	TIL31	A
SE-5450-3	Spectronics	IR Emitter	TIL31	A
SE-5451-1	Spectronics	IR Emitter	TIL31	A
SE-5451-2	Spectronics	IR Emitter	TIL31	A
SE-5451-3	Spectronics	IR Emitter	TIL31	A
SE-6450-2	Spectronics	IR Emitter	TIXL13	A
SE-6450-3	Spectronics	IR Emitter	TIXL13	A
SE-6451-1	Spectronics	IR Emitter	TIXL13	A
SE-6451-2	Spectronics	IR Emitter	TIXL13	A
SE-6451-3	Spectronics	IR Emitter	TIXL13	A
SE-6452-1	Spectronics	IR Emitter	TIXL13	A
SE-6452-2	Spectronics	IR Emitter	TIXL13	A
SE-6452-3	Spectronics	IR Emitter	TIXL13	A
SE-6474-020	Spectronics	IR Emitter	TIXL13	A
SE-6474-030	Spectronics	IR Emitter	TIXL12	A
SE-6474-040	Spectronics	IR Emitter	TIXL12	A
SE-6477-030	Spectronics	IR Emitter	TIXL15	A
SE-6477-040	Spectronics	IR Emitter	TIXL14	A
SE-6477-060	Spectronics	IR Emitter	TIXL14	A
SE-6478-2	Spectronics	IR Emitter	TIXL16B	B
SG-1001	RCA	IR Emitter	TIL24	E
SG-1002	RCA	IR Emitter	TIL24	E
SG-1003	RCA	IR Emitter	TIL24	E
SG-1004	RCA	IR Emitter	TIL24	E
SGD-100A	EG&G	Photodiode	TIXL80	D, E
SLA-1	OPCOA	Visible Numeric Display	TIL312	C

Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
SLA-1R	OPCOA	Visible Numeric Display	TIL312	C
SLA-2	OPCOA	Visible Numeric Display	TIL327	C
SLA-3	OPCOA	Visible Numeric Display	TIL321	D, E
SLA-7	OPCOA	Visible Numeric Display	TIL312	C
SLA-8	OPCOA	Visible Numeric Display	TIL312	C
SLA-9	OPCOA	Visible Numeric Display	TIL327	C
SLA-10	OPCOA	Visible Numeric Display	TIL327	C
SLA-11	OPCOA	Visible Numeric Display	TIL314	C
SLA-11R	OPCOA	Visible Numeric Display	TIL314	C
SLA-12	OPCOA	Visible Numeric Display	TIL328	C
SLA-18	OPCOA	Visible Numeric Display	TIL314	C
SLA-20	OPCOA	Visible Numeric Display	TIL328	C
SLA-21	OPCOA	Visible Numeric Display	TIL316	C
SLA-21R	OPCOA	Visible Numeric Display	TIL316	C
SLA-22	OPCOA	Visible Numeric Display	TIL329	C
SLA-28	OPCOA	Visible Numeric Display	TIL316	C
SLA-30	OPCOA	Visible Numeric Display	TIL329	C
SSC-1003	Spectronics	Opto-coupler	TIL116	D, E
SSL3	GE	IR Emitter	TIL31	C
SSL3F	GE	IR Emitter	TIL31	C
SSL4	GE	IR Emitter	TIL31	C
SSL5A	GE	IR Emitter	TIL31	C
SSL5B	GE	IR Emitter	TIL31	C
SSL5C	GE	IR Emitter	TIL31	C
SSL12	GE	Visible Emitter	TIL209A	B, C
SSL15	GE	IR Emitter	TIL24	E
SSL22	GE	Visible Emitter	TIL220	E
SSL22L	GE	Visible Emitter	TIL220	C
SSL34	GE	IR Emitter	TIL31	C
SSL35	GE	IR Emitter	TIL31	C
SSL54	GE	IR Emitter	TIL31	C
SSL55B	GE	IR Emitter	TIL31	C
SSL55C	GE	IR Emitter	TIL31	C
SSL55LC	GE	IR Emitter	TIL31	C
SSL65	GE	IR Emitter	TIL23	C
SSL140	GE	Visible Numeric Display	TIL310	C
SSL190	GE	Visible Numeric Display	TIL310	E
SSL212	GE	Visible Emitter	TIL209A	B, C
SSL315	GE	IR Emitter	TIL24	E
ST/A71	Sensor Technology	Phototransistor Tape Reader Array, 9-Element	TIL132	E
ST/A72	Sensor Technology	Phototransistor Tape Reader Array, 9-Element	TIL132	E
STPT40	Sensor Technology	Phototransistor	LS400	A
STPT60	Sensor Technology	Phototransistor	LS600	A
STPT100	Sensor Technology	Phototransistor	TIL65	B, C
STPT100A	Sensor Technology	Phototransistor	TIL66	B, C
STPT100B	Sensor Technology	Phototransistor	TIL66	B, C
STPT110	Sensor Technology	Phototransistor	TIL65	B, C
STPT110A	Sensor Technology	Phototransistor	TIL66	B, C

INTERCHANGEABILITY GUIDE

2

Other Manufacturers' Part Number	Manufacturer	Description	Nearest TI Equivalent	Code
STPT100B	Snesor Technology	Phototransistor	TIL66	B, C
STPT120	Sensor Technology	Phototransistor	TIL67	B, C
STPT120A	Sensor Technology	Phototransistor	TIL67	B, C
STPT120B	Sensor Technology	Phototransistor	TIL67	B, C
STPT130	Sensor Technology	Phototransistor	TIL67	B, C
STPT130A	Sensor Technology	Phototransistor	TIL67	B, C
STPT130B	Sensor Technology	Phototransistor	TIL67	B, C
STPT300	Sensor Technology	Phototransistor	TIL67	B, C
STPT310	Sensor Technology	Phototransistor	TIL81	B, C
STRA-850	Sensor Technology	1-Channel Source/Sensor Reflective Assembly	TIL139	E
TA7437R	RCA	IR Emitter	TIL24	E
TA7762R	RCA	IR Emitter	TIL24	E
UDT-400	United Detector Technology	Photodiode	TIXL80	B, C
UDT-600	United Detector Technology	Photodiode	TIXL80	B, C
XAN51	Xcitron	Visible Numeric Display	TIL314	A
XAN52	Xcitron	Visible Numeric Display	TIL314	A
XAN54	Xcitron	Visible Numeric Display	TIL315	C
XAN71	Xcitron	Visible Numeric Display	TIL312	A
XAN72	Xcitron	Visible Numeric Display	TIL312	A
XAN74	Xcitron	Visible Numeric Display	TIL313	C
XAN81	Xcitron	Visible Numeric Display	TIL316	A
XAN82	Xcitron	Visible Numeric Display	TIL316	A
XAN84	Xcitron	Visible Numeric Display	TIL317	C
XAN600G	Xcitron	Visible Numeric Display	TIL323	D, E
XAN600R	Xcitron	Visible Numeric Display	TIL321	D, E
XAN600Y	Xcitron	Visible Numeric Display	TIL325	D, E
XC209	Xcitron	Visible Emitter	TIL209A	A
XC520	Xcitron	Visible Emitter	TIL221	C
XC522	Xcitron	Visible Emitter	TIL220	C
XC524	Xcitron	Visible Emitter	TIL220	C
XC526	Xcitron	Visible Emitter	TIL220	C
XC554-3	Xcitron	Visible Emitter	TIL220	B
XC554-6	Xcitron	Visible Emitter	TIL220	B
XC554-9	Xcitron	Visible Emitter	TIL220	B, C
XC556	Xcitron	Visible Emitter	TIL220	B
YAG-100	EG&G	Photodiode	TIXL80	B, C

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Infrared Emitters

3

3

INFRARED EMITTERS
QUICK REFERENCE GUIDE

DEVICE	POWER OUTPUT MIN mW	@ I_F mA	θ_{HI}	V_F MAX V	@ I_F mA	λ_p TYP μm	FEATURES
TIL23†	0.4	50	35°	1.5	50	0.94	Pill package for mounting on double-sided printed circuit board
TIL24†	1	50	35°	1.5	50	0.94	
TIL25†	0.75	50	35°	1.5	50	0.94	
TIL26	1	35	175°	1.9	35	0.94	Low-cost header with epoxy lens
TIL31	3.3	100	10°	1.75	100	0.94	Hermetically sealed TO-18 package
TIL32	0.5	20	35°	1.6	20	0.94	Low-cost plastic package
TIL33	2.5	100	80°	1.75	100	0.94	Hermetically sealed TO-18 package
TIL34	1.6	100	10°	1.75	100	0.94	Hermetically sealed TO-18 package
TIL41	0.5	20		1.6	20	0.94	Single element
TIL42	0.5‡	20		1.6	20	0.94	2-element array
TIL43	0.5‡	20		1.6	20	0.94	3-element array
TIL44	0.5‡	20		1.6	20	0.94	4-element array
TIL45	0.5‡	20		1.6	20	0.94	5-element array
TIL46	0.5‡	20		1.6	20	0.94	6-element array
TIL47	0.5‡	20		1.6	20	0.94	7-element array
TIL48	0.5‡	20		1.6	20	0.94	8-element array
TIL49	0.5‡	20		1.6	20	0.94	9-element array
TIL50	0.5‡	20		1.6	20	0.94	10-element array

†High-reliability versions (TIL23HR, TIL24HR, TIL25HR) are also available.
‡Output per element
For additional infrared emitters, see the *Special Electro-optical Components* **section of this book.**

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TYPES TIL23, TIL24, TIL25
P-N GALLIUM ARSENIDE INFRARED-EMITTING DIODES

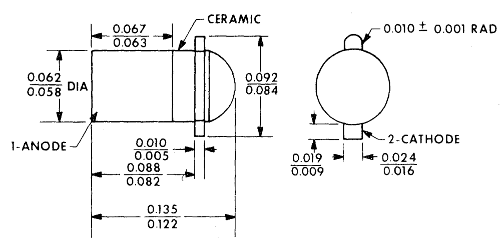
BULLETIN NO. DL-S 7611312, FEBRUARY 1970–REVISED JANUARY 1976

3

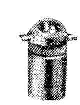
DESIGNED TO EMIT NEAR-INFRARED RADIATION WHEN FORWARD BIASED

- Output Spectrally Compatible with Silicon Sensors
- High Power Efficiency, Typically 1.5 Percent at 25°C
- High Power Output, Typically 2.0 mW at 25°C
- Small Size Permits Matrix Assembly Directly into Printed Circuit Boards
- High Radiant Intensity, Typically 7 mW/sr for TIL24

mechanical data



ALL DIMENSIONS ARE IN INCHES



4 TIMES ACTUAL SIZE

absolute maximum ratings

Reverse Voltage at 25°C Case Temperature	2 V
Continuous Forward Current at 25°C Case Temperature (See Note 1)	100 mA
Operating Case Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Soldering Temperature (3 Minutes)	240°C

† Radiant intensity is calculated from $I_e = P_O/2\pi(1-\cos 0.5\theta_{HI})$. One steradian is the solid angle at the center of a sphere subtended by a portion of the surface area equal to the square of the radius of the sphere. There are 4π steradians in a complete sphere.

NOTE 1: Derate linearly to 125°C case temperature at the rate of 1 mA/°C. For pulsed operation at higher currents, see Figures 8 and 9.

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operating characteristics at 25°C case temperature

PARAMETER	TEST CONDITIONS	TIL23			TIL24			TIL25			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
P_O Radiant Power Output	I_F = 50 mA	0.4			1			0.75			mW
λ_p Wavelength at Peak Emission		915	940	975	915	940	975	915	940	975	nm
$\Delta\lambda$ Spectral Bandwidth			50	75		50	75		50	75	nm
θ_{HI} Half-Intensity Beam Angle			35°			35°			35°		
V_F Static Forward Voltage			1.25	1.5			1.5			1.5	V

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

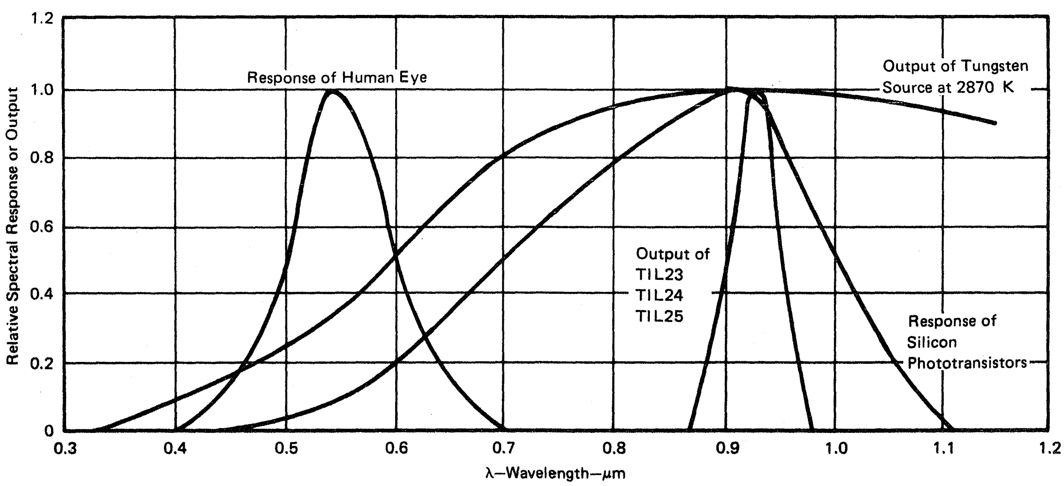

FIGURE 1

TEXAS INSTRUMENTS
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TYPICAL CHARACTERISTICS

RELATIVE PHOTON INTENSITY
vs
ANGULAR DISPLACEMENT

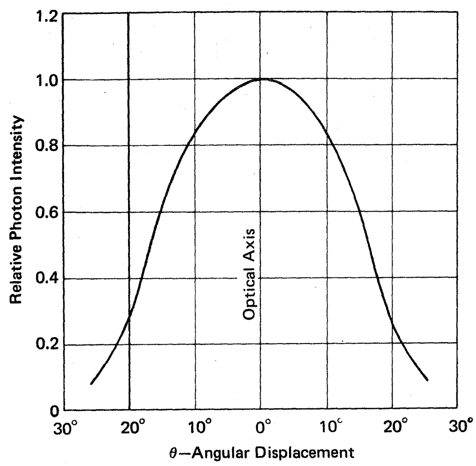

FIGURE 2

RELATIVE POWER OUTPUT
vs
CASE TEMPERATURE

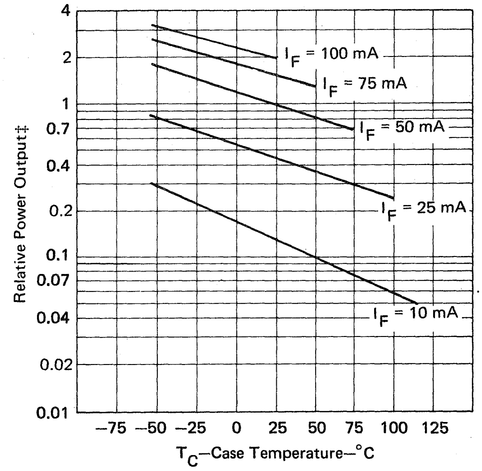

FIGURE 3

CHANGE IN WAVELENGTH OF PEAK INTENSITY
vs
CASE TEMPERATURE

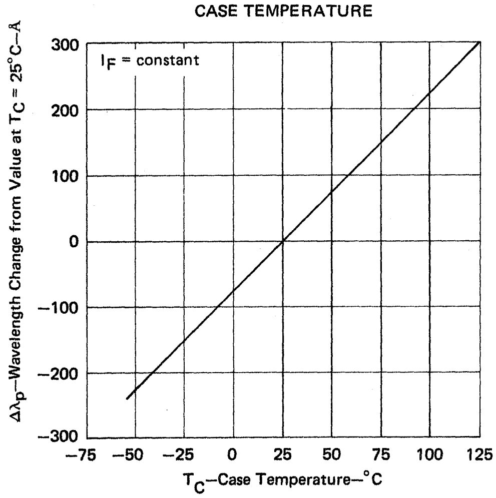

FIGURE 4

RELATIVE POWER OUTPUT
vs
FORWARD CURRENT

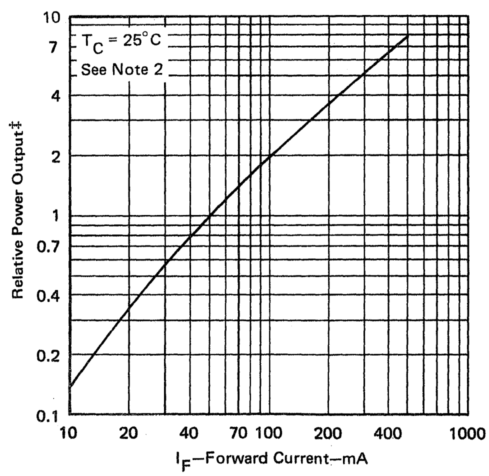

FIGURE 5

NOTE 2: These parameters must be measured using pulse techniques: t_W = 0.04 ms, duty cycle ≤ 10%.
‡Normalized to output at I_F = 50 mA, T_C = 25°C.

TYPICAL CHARACTERISTICS

TIL23

FORWARD CONDUCTION CHARACTERISTICS

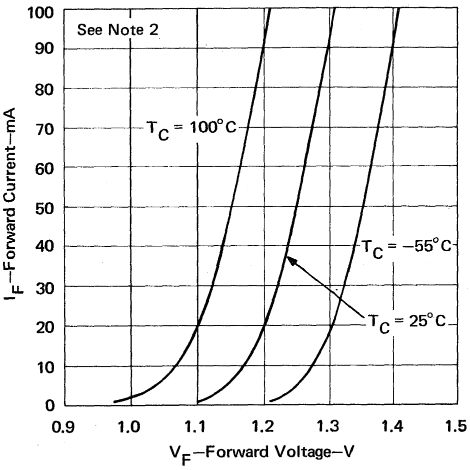

FIGURE 6

COUPLING CHARACTERISTICS OF TIL23, TIL24, AND TIL25 WITH TIL602, TIL606, TIL610, OR TIL614

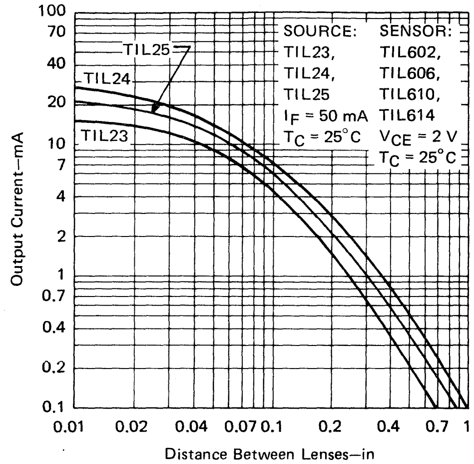

FIGURE 7

NOTE 2: These parameters must be measured using pulse techniques: t_w = 0.04 ms, duty cycle ⩽ 10%.

THERMAL CHARACTERISTICS

MAXIMUM PULSE WIDTH vs FORWARD CURRENT

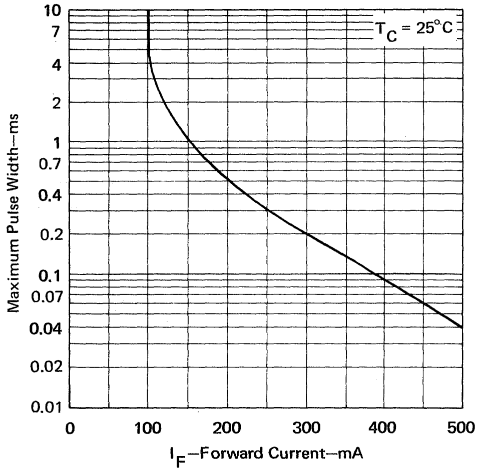

FIGURE 8

MAXIMUM DUTY CYCLE vs FORWARD CURRENT

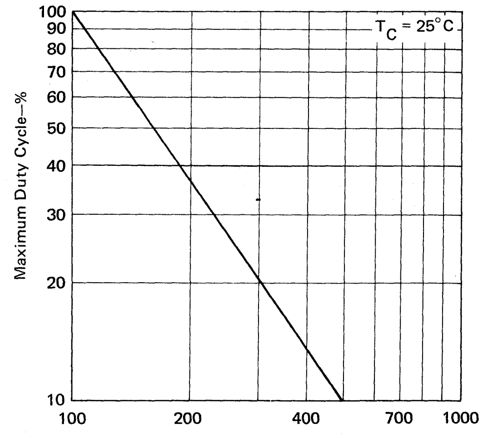

FIGURE 9

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P-N GALLIUM ARSENIDE INFRARED-EMITTING DIODE

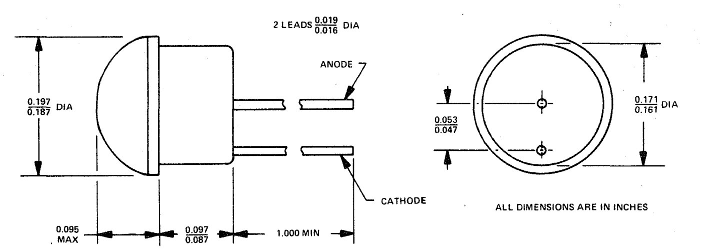
BULLETIN NO. DL-S 7611574, MARCH 1974—REVISED MARCH 1976

NOT RECOMMENDED FOR NEW DESIGN

FOR NEW DESIGN, USE TIL31

mechanical data

BOTH LEADS ELECTRICALLY INSULATED FROM CASE



absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature . . . . 2 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note) . . . . 50 mA
Operating Free-Air Temperature Range . . . . −40°C to 80°C
Storage Temperature Range . . . . −40°C to 85°C
Lead Temperature 1/16 Inch from Case for 10 Seconds . . . . 240°C

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 35 mA	1			mW
λ_p	Wavelength at Peak Emission		915	940	975	nm
$\Delta\lambda$	Spectral Bandwidth			50	75	nm
θ_{HI}	Half-Intensity Beam Angle			175°		
V_F	Static Forward Voltage			1.2	1.9	V

NOTE: Derate linearly to 80°C free-air temperature at the rate of 0.91 mA/°C.

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TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

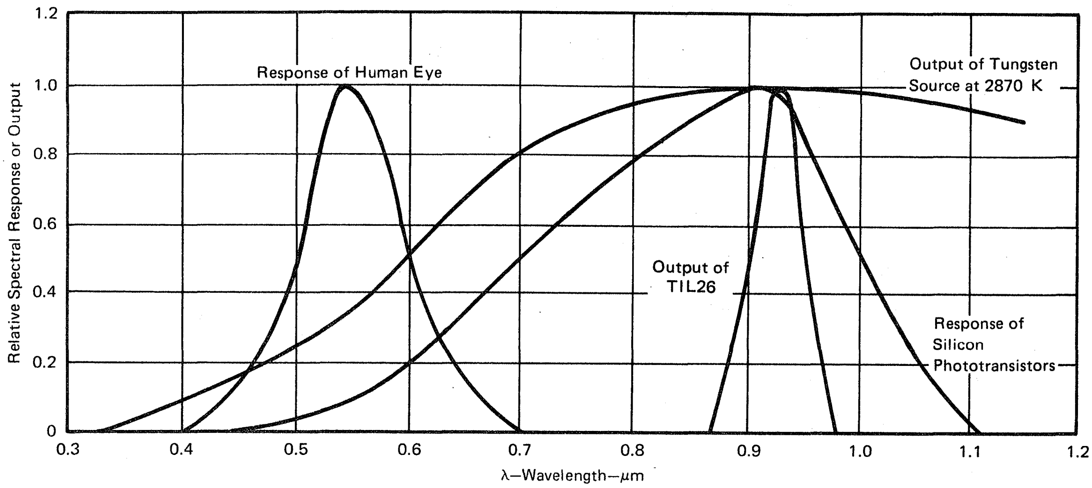

FIGURE 1

FORWARD CONDUCTION CHARACTERISTICS

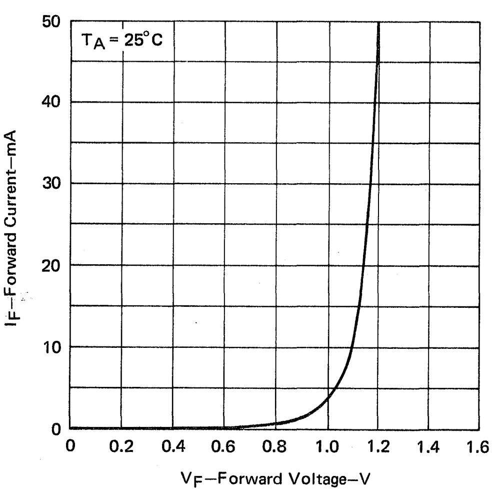

FIGURE 2

RELATIVE POWER OUTPUT
vs
FORWARD CURRENT

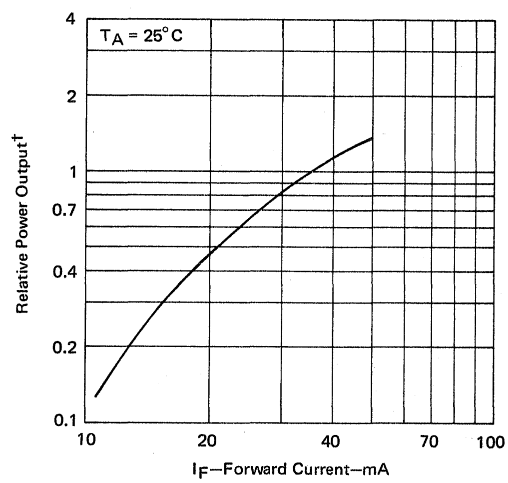

FIGURE 3

†This curve normalized to output at I_F = 35 mA, T_A = 25°C.

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BULLETIN NO. DL-S 7612209, NOVEMBER 1974—REVISED MARCH 1976

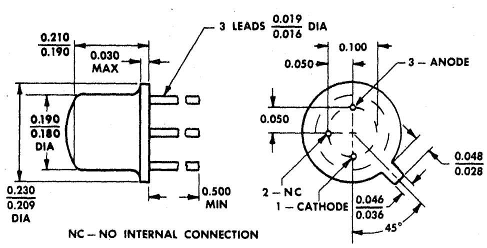
DESIGNED TO EMIT NEAR-INFRARED RADIATION WHEN FORWARD BIASED

- Output Spectrally Compatible with Silicon Sensors
- Mechanically Compatible with TIL81
- Typical Applications Include Card Readers, Encoders, Intrusion Alarms, Sector Sensors, Level Indicators, and Beginning-of-Tape/End-of-Tape Indicators

3

mechanical data

Each device is in a hermetically sealed welded case similar to JEDEC TO-18 with window. The TIL31 and TIL34 have convex lenses while that of the TIL33 is essentially flat. A coin header is used to increase dissipation capability. All TO-18 registration notes also apply to this outline. Approximate weight is 0.35 gram. All metal surfaces are gold plated.

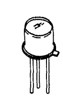


THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE

MAXIMUM WINDOW EXTENSION FROM TOP OF CASE IS:
0.040 FOR TIL31 AND TIL34
0.010 FOR TIL33
MINIMUM DIAMETER IS 0.140

THE WINDOW IS CORNING 7052 (OR EQUIVALENT) GLASS

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



absolute maximum ratings

Reverse Voltage at 25°C Case Temperature	2 V
Continuous Forward Current at 25°C Case Temperature (See Note 1)	200 mA
Operating Case Temperature Range	−65°C to 150°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

operating characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TIL31			TIL33			TIL34			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
P_O	Radiant Power Output	I_F = 100 mA	3.3	6		2.5	5		1.6	3		mW
λ_p	Wavelength at Peak Emission		915	940	975	915	940	975	915	940	975	nm
$\Delta\lambda$	Spectral Bandwidth			50	75		50	75		50	75	nm
θ_{HI}	Half-Intensity Beam Angle			10°			80°			10°		
V_F	Static Forward Voltage			1.4	1.75		1.4	1.75		1.4	1.75	V
t_r	Radiant Pulse Rise Time‡	I_{FM} = 50 mA, t_w = 2 μs,		600			600			600		ns
t_f	Radiant Pulse Fall Time‡	f = 45 kHz		350			350			350		

†Radiant intensity is calculated from $I_e = P_O/2\pi(1-\cos 0.5\theta_{HI})$. One sterdian is the solid angle at the center of a sphere subtended by a portion of the surface area equal to the square of the radius of the sphere. There are 4π steradians in a complete sphere.

‡Radiant pulse rise time is the time required for a change in radiant intensity from 10% to 90% of its peak value for a step change in current; radiant pulse fall time is the time required for a change in radiant intensity from 90% to 10% of its peak value for a step change in current.

NOTE 1: Derate linearly to 150°C case temperature at the rate of 1.6 mA/°C.

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TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

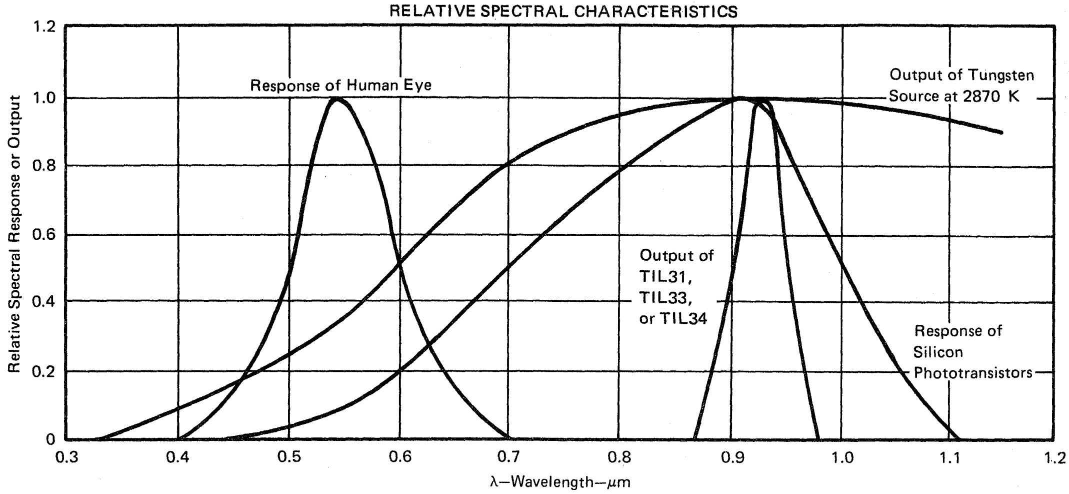

FIGURE 1

RELATIVE POWER OUTPUT vs CASE TEMPERATURE

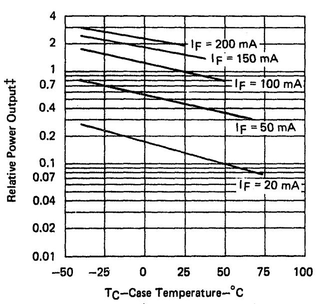

FIGURE 2

RELATIVE POWER OUTPUT vs FORWARD CURRENT

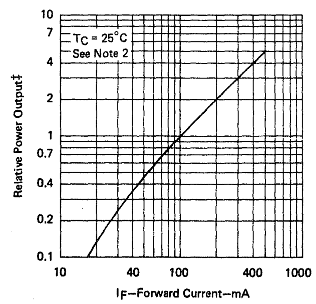

FIGURE 3

CHANGE IN WAVELENGTH AT PEAK EMISSION vs CASE TEMPERATURE

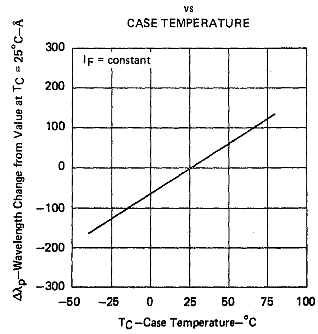

FIGURE 4

TIL31, TIL34
RELATIVE RADIANT INTENSITY vs ANGULAR DISPLACEMENT

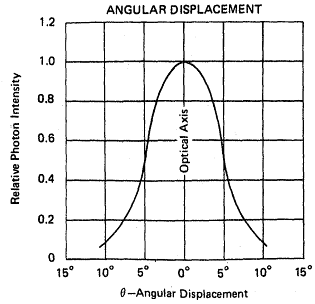

FIGURE 5

TIL33
RELATIVE RADIANT INTENSITY vs ANGULAR DISPLACEMENT

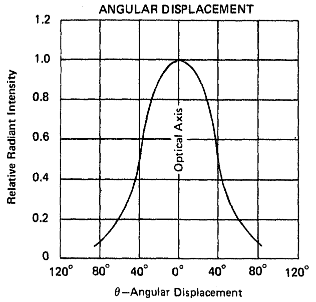

FIGURE 6

FORWARD CONDUCTION CHARACTERISTICS

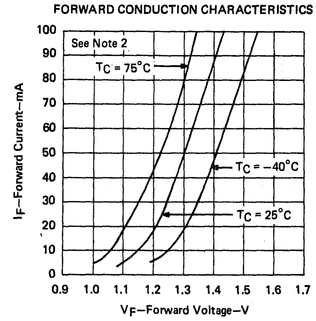

FIGURE 7

NOTE 2: This parameter must be measured using pulse techniques. t_w = 0.04 ms, duty cycle ≤ 10%.
‡Normalized to output at I_F = 10 mA, T_C = 25° C.

PRINTED IN U.S.A. 1174

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P-N GALLIUM ARSENIDE INFRARED-EMITTING DIODE

BULLETIN NO. DL-S 7611542, SEPTEMBER 1971—REVISED MARCH 1976

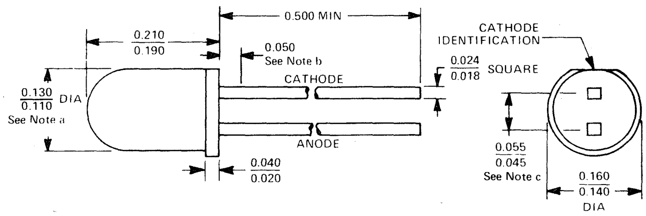
DESIGNED TO EMIT NEAR-INFRARED RADIATION WHEN FORWARD BIASED

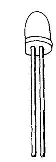
- **Output Spectrally Compatible with Silicon Sensors**
- **High Power Efficiency . . . Typically 5 Percent at 25°C**
- **High Power Output . . . Typically 1.2 mW at 25°C**
- **High Radiant Intensity . . . Typically 4 mW per Steradian†**
- **Plastic Package with Two Leads for Ease of Handling**

3

mechanical data

This device has a clear molded plastic body.





NOTES: a. This diameter is measured 0.005 inch from the shoulder.
b. Within this zone the package contour is not controlled.
c. Lead spacing is measured where the leads emerge from the package.
d. All dimensions are in inches.

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature	2 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	40 mA
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 85°C
Lead Temperature 1/16 Inch from Case for 5 Seconds	240°C

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 20 mA	0.5	1.2		mW
λ_p	Wavelength at Peak Emission		915	940	975	nm
$\Delta\lambda$	Spectral Bandwidth			50	75	nm
θ_{HI}	Half-Intensity Beam Angle			35°		
V_F	Static Forward Voltage			1.2	1.6	V
t_r	Radiant Pulse Rise Time‡	I_{FM} = 20 mA, t_w = 2 μs, f = 45 kHz		600		ns
t_f	Radiant Pulse Fall Time‡			350		ns

†Radiant intensity is calculated from $I_e = P_O/2\pi(1-\cos 0.5\theta_{HI})$. One steradian is the solid angle at the center of a sphere subtended by a portion of the surface area equal to the square of the radius of the sphere. There are 4π steradians in a complete sphere.

‡Radiant pulse rise time is the time required for a change in radiant power output from 10% to 90% of its peak value for a step change in current; radiant pulse fall time is the time required for a change in radiant power output from 90% to 10% of its peak value for a step change in current.

NOTE 1: Derate linearly to 80°C free-air temperature at the rate of 0.73 mA/°C.

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TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

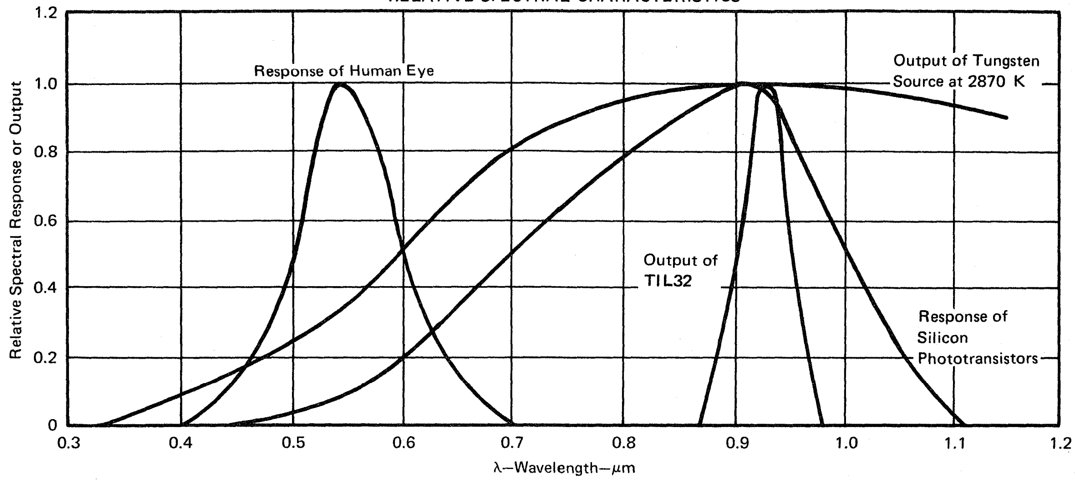

FIGURE 1

RELATIVE POWER OUTPUT vs FREE-AIR TEMPERATURE

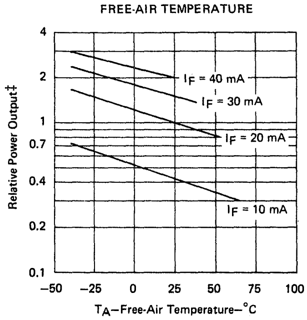

FIGURE 2

RELATIVE POWER OUTPUT vs FORWARD CURRENT

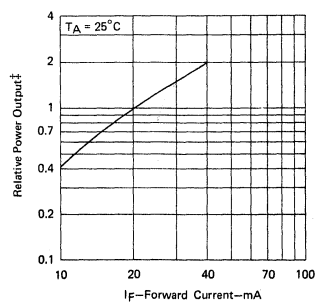

FIGURE 3

CHANGE IN WAVELENGTH OF PEAK INTENSITY vs FREE-AIR TEMPERATURE

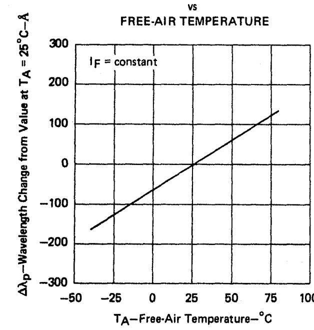

FIGURE 4

RELATIVE PHOTON INTENSITY vs ANGULAR DISPLACEMENT

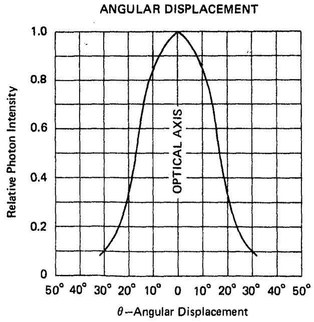

FIGURE 5

COUPLING CHARACTERISTICS OF TIL32 WITH TIL78

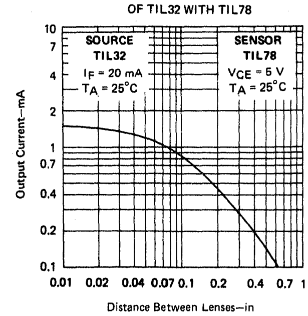

FIGURE 6

FORWARD CONDUCTION CHARACTERISTICS

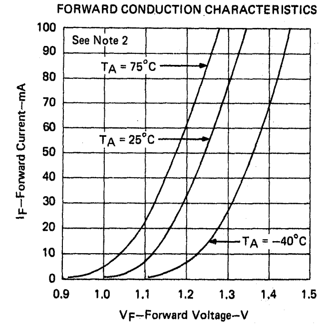

FIGURE 7

NOTE 2: This parameter must be measured using pulse techniques: t_w = 0.04 ms, duty cycle ⩽ 10%.

‡Normalized to Output at I_F = 20 mA, T_A = 25°C.

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GALLIUM ARSENIDE INFRARED-EMITTING DIODE ARRAYS

BULLETIN NO. DL-S 7412230, NOVEMBER 1974

3

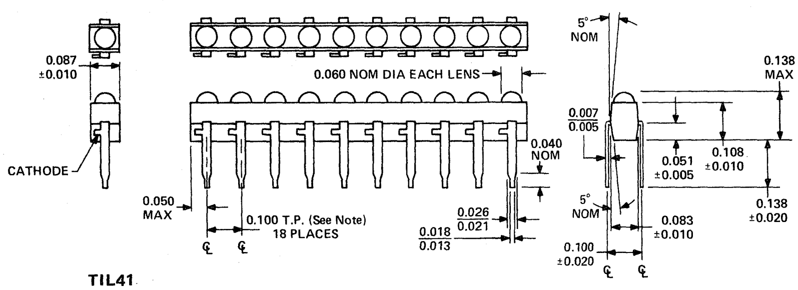
DESIGNED TO EMIT NEAR-INFRARED RADIATION WHEN FORWARD BIASED

- Single Element or Arrays from 2 to 10 Elements
- Recommended for Application in Tape and Card Readers
- Spectrally Matched to TIL621 thru TIL630 Sensor Arrays
- Center-to-Center Spacing of 0.100 Inch

TYPE NUMBER	TIL41	TIL42	TIL43	TIL44	TIL45	TIL46	TIL47	TIL48	TIL49	TIL50
NUMBER OF ELEMENTS	1	2	3	4	5	6	7	8	9	10

mechanical data

Each device has an orange molded transparent epoxy body with silver-plated leads.



TIL41 SINGLE ELEMENT TOP AND SIDE VIEWS

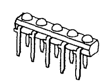
TIL50 10-ELEMENT ARRAY TOP AND SIDE VIEWS

TIL41–TIL50 END VIEW

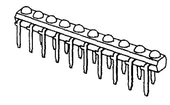
NOTE: Each pin centerline is located within 0.010 of its true longitudinal position.

All dimensions are in inches unless otherwise noted.

TIL41



TIL45



TIL50

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature	2 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	40 mA
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 100°C
Lead Temperature 1/16 Inch below Seating Plane for 3 Seconds	240°C

NOTE 1: Derate linearly to 80°C free-air temperature at the rate of 0.73 mA/°C.

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operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	$I_F = 20$ mA	0.5	1.2		mW
λ_p	Wavelength at Peak Emission		915	940	975	nm
$\Delta\lambda$	Spectral Bandwidth			60	75	nm
V_F	Static Forward Voltage			1.2	1.6	V
I_R	Static Reverse Current	$V_R = 2$ V		0.1	100	μA
t_r	Radiant Pulse Rise Time†	$I_{FM} = 20$ mA, $t_w = 2$ μs, f = 45 kHz		600		ns
t_f	Radiant Pulse Fall Time†			350		

†Radiant pulse rise time is the time required for a change in radiant power output from 10% to 90% of its peak value for a step change in current; radiant pulse fall time is the time required for a change in radiant power output from 90% to 10% of its peak value for a step change in current.

TYPICAL CHARACTERISTICS

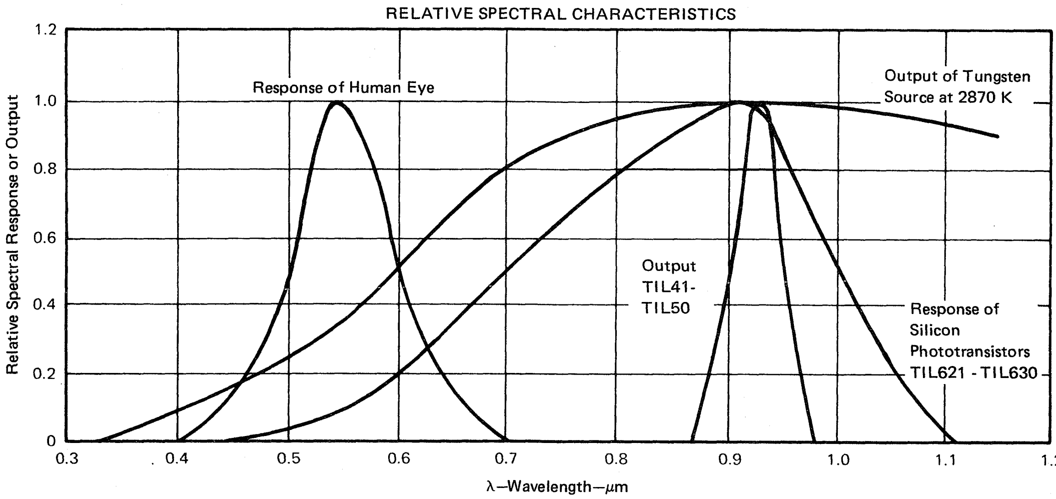

FIGURE 1

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MEASURING THE OUTPUT OF INFRARED-EMITTING AND LIGHT-EMITTING DIODES

Ronald D. Grotti and Larry D. Major
Optoelectronics Department

Making accurate radiant-energy measurements involves, if not a little black magic, at least a relatively complicated commercial instrument and a skilled operator. However, the increased use of infrared-emitting diodes (IRED's) and light-emitting diodes (LED's) as a precision system component has necessitated the development of equipment suitable for measuring radiant energy from IRED's and LED's in the designer's lab, in the quality control lab, and on the production line. This equipment must be easy to use, provide the necessary accuracy, be calibratable, and be inexpensive.

To develop such equipment requires the selection of a suitable photodetector and the development of the proper calibration and operation procedures. This report describes a method that has been used in the Texas Instruments Optoelectronic Device Department for measuring the output of its radiation-emitting diode products. The apparatus consists simply of a photovoltaic detector connected directly to an ammeter, with a special mechanical fixture to prevent escape of radiant energy.

SELECTION OF DETECTOR

Detectors that might be considered for measuring IRED and LED output include thermopiles, photocells, photodiodes, photomultipliers and photovoltaic cells. To show why the photovoltaic cell was chosen for this application, a review of pertinent detector characteristics is in order.

Thermopiles can be excellent primary detecting devices, but are generally unsuitable for most laboratory and quality control types of service. Not only are they difficult to apply properly, but they are costly, lose their calibration when mishandled, and have an inadequate frequency response.

Photodiodes have good frequency capabilities, are reasonably priced, and are being used in pulse and high-frequency applications. However, most IRED's and LED's are tested under low-frequency conditions, and therefore frequency response is not a critical sensor parameter. Because the photodiode must be electronically biased, a well-regulated bias supply is required to ensure consistent results.

Good sensitivity and frequency response plus a large detection area are some photomultiplier features. But multi-element phototubes are expensive, require high-voltage supplies, and since output is a function of supply voltage, stability problems can arise. Also, if improperly applied, photomultipliers can saturate, causing errors and possibly permanent tube damage.

Photovoltaic cells—particularly the solar-cell variety—have a large active area, good long-term stability, and good spectral matching, are easy to use, and are inexpensive. The frequency response from dc to 100 kHz, although less than that of the photomultiplier and photodiode, is satisfactory for this application. These factors, combined with the fact that power or bias supplies are not required, makes the solar cell appear to have the best combination of qualities for this application.

Using the photovoltaic cell to precisely measure the emitter output and determine its quantum efficiency requires detailed knowledge of the cell, the emitter, and how they are optically coupled. Such knowledge depends not only on the mathematical characterization of the two devices, but on an accurate calibration of the photovoltaic cell. Once these steps have been accomplished, the emitter's power output and its quantum efficiency can be calculated using only two measured values – the emitter's input current and the cell's output current.

THE PHOTOVOLTAIC CELL

Before describing how the photovoltaic cell is calibrated, a few comments on the basic characteristics of this semiconductor device are in order. It is not necessary for our purposes to discuss the theory of operation in detail. Suffice it to say that electron-hole pairs are generated within the device as a function of impinging photons. Only those photons that have a quantum energy larger than the band gap between the valence band and the conduction band generate electron-hole pairs. The lower-energy photons simply transmit through the cell and do not cause an output. The ratio of electrons generated to the total number of incident photons is the cell's quantum efficiency, and is defined as

$$\eta_{SC} = \frac{\text{electrons generated/sec}}{\text{incident photons/sec}}$$

It is necessary to note that the cell's quantum efficiency is a function of the wavelength (Figure 1). This fact is particularly important because the sensor specifications are often based on the device's sensitivity to a particular wavelength. This quantum efficiency curve can be shaped through various means including the deposition of anti-reflection coatings on the photovoltaic cell's surface.

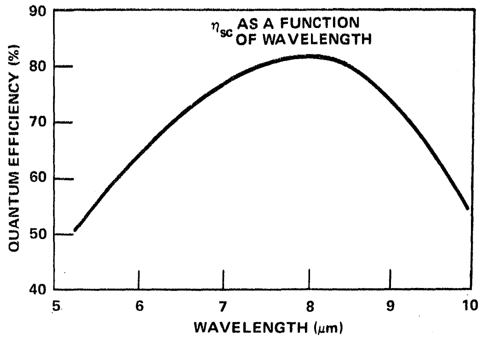

FIGURE 1. Photodetector Quantum Efficiency Varies as a Function of Wavelength, Thus Making Calibration at a Number of Wavelengths Necessary for General Use

CELL CALIBRATION

Before using the photovoltaic cell to measure the IRED or LED power output, the cell must be calibrated. This calibration is a two-step process, with the first step being the accurate determination of the cell's relative response. This determination is made using a grating monochromator, a tungsten light source, and a thermocouple detector that has a flat response in the spectral region of 500 nm to 1000 nm. Two curves are obtained, one using the thermocouple detector to measure the tungsten source's output and the other using the photovoltaic detector to measure the same output.

By dividing the photovoltaic cell response by the thermocouple response, the relative response of the cell is obtained. The relative response curve allows the measurement of radiation sources with different spectral characteristics to be accurately compared. However, to determine the actual power generated by a particular source using this cell requires another calibration step in which the photovoltaic cell output is determined when illuminated by a radiation source with a known power output. To accomplish this goal, the output of three monochromatic sources (gallium arsenide IRED, helium-neon laser, and argon laser) are measured by the cell being calibrated and by an Eppley thermopile. The quantum efficiency of the cell at the wavelength of each emitter is then found by using the optical power equation:

$$\eta_{sc} = \left(\frac{I_L}{\text{optical power}}\right)\left(\frac{\text{energy}}{\text{photon}}\right)$$

where I_L is the short-circuit current from the photovoltaic cell under test and optical power is the measurement made by the thermopile.

The three quantum efficiencies are then plotted, and a curve is generated that allows the cell to be used to measure accurately any impinging light of known spectral characteristics.

MEASUREMENT PROCEDURE

To employ this calibrated detector in a radiation-emitting diode testing system, it is necessary to develop the relationships that can describe the diode's quantum efficiency.

The diode output is directly proportional to the emitted photon energy and quantity per unit of time. The relation between energy E and wavelength λ is defined as

$$\lambda = \frac{1.24}{E} \text{ or } E = \frac{1.24}{\lambda} \qquad \text{(units are } \mu\text{m and eV)}$$

Energy, and therefore wavelength, of any given photon emitted from an IRED or LED source fall within a distribution curve such as that shown in Figure 2 for a GaAs IRED. To be absolutely accurate in calculating the optical power output of a solid-state source requires a time-consuming graphical integration using Figure 1 and Figure 2. Fortunately, all photons emitted by a monochromatic source have the same energy. Since it is a valid assumption to consider the IRED to be monochromatic, the IRED's optical power can be described to a first approximation without any noticeable error.

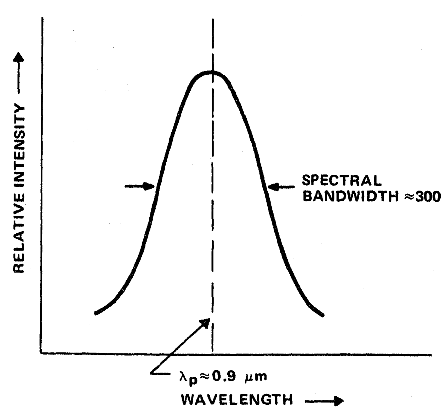

FIGURE 2. Spectral Characteristics of GaAs Diode Indicate that the Device is Nearly Monochromatic

For simplicity of calculation, let us assume that all photons generated by the IRED are collected by the photovoltaic cell. Therefore, considering the ammeter as a load consisting of a calibrated resistor and microvoltmeter, (Figure 3), the current I_L (neglecting the internal resistance R_{shunt} of the photocell) is proportional to the number of photons striking the surface:

$$I_L = \left(\frac{\text{electrons}}{\text{sec}}\right) (1.602 \times 10^{-19})$$

and

$$I_L = \eta_{sc} \left(\frac{\text{photons}}{\text{sec}}\right) (1.602 \times 10^{-19})$$

therefore,

$$\text{photons/sec} = \frac{I_L}{\eta_{sc}\,(1.602 \times 10^{-19})}$$

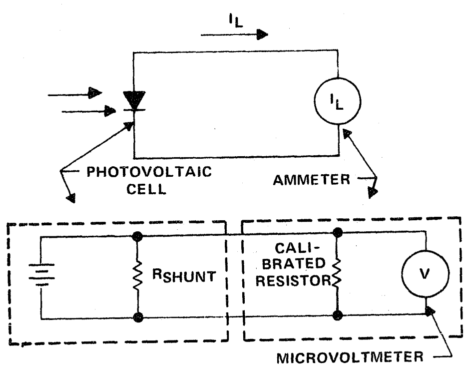

FIGURE 3. Equivalent Circuit of a Photovoltaic Cell (Silicon Solar Cell) Connected to the Ammeter Used to Measure Short Circuit Current

Knowing I_L, we can now calculate the emitter quantum efficiency η_{em} and optical power P_O:

$$\eta_{em} = \frac{I_L}{\eta_{sc}\, I_D} \qquad \text{where } I_D \text{ is IRED current}$$

$$P_O = \left(\frac{I_L}{\eta_{sc}}\right) \cdot \left(\frac{\text{energy}}{\text{photon}}\right)$$

Using these equations, we can indeed determine both the quantum efficiency and the optical power generated by the IRED under conditions where all the power emitted is collected by the photovoltaic cells. To ensure the photovoltaic cell receives all emitted photons, it is necessary to build special testing jigs using detectors either singly or in arrays. (See Figures 4 and 5). In either case, the test procedures are the same. However, if such jigs are not possible, then the percentage of energy emitted that actually reaches the detector must be included in the calculation. This fraction can be determined by dividing the total power emitted by the steradian relationship between the detector and the emitter, the total number of steradians being equal to the aperture area of the detector divided by the square of the distance between the emitter and the detector surface.

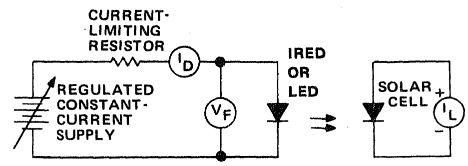

FIGURE 4. Calibrating the Test Setup

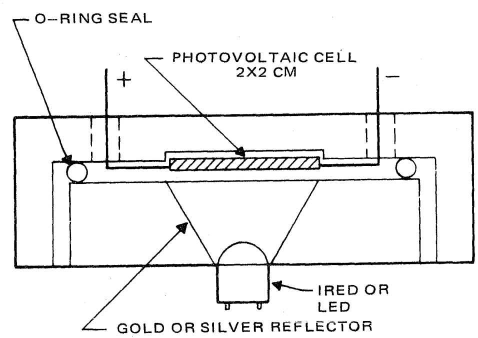

FIGURE 5. Test Jig for Capturing the Total Diode Output with a Single Photovoltaic Cell

TESTING PRECAUTIONS

Generally, gallium arsenide and gallium arsenide phosphide (GaAsP) infrared emitters provide an output signal I_L large enough that an ammeter may be used to measure the cell's short-circuit current directly. The measurement of GaAsP visible-light-emitting diodes and tests such as radiant intensity measurements usually produce signal levels that require a calibrated resistor and a microvoltmeter. The important point is that the input impedance of the measuring instrument must be less than 1/10 the value of R_{shunt} to prevent lowering the output of the cell. The exact value of R_{shunt} for photovoltaic cells is difficult to measure, but it is usually in the order of 10 to 30 kΩ. If the cell has been mistreated, the R_{shunt} may be as low as 1 kΩ or less. Thus, if an electronic ammeter is used in the 3×10^{-6} ampere range, as may be required for testing GaAsP LED's, the input meter impedance of 300 to 1000 Ω approaches the critical value of the typical solar cell. Thus, these low-level measurements must be made using the resistor-microvoltmeter technique.

The second problem occurs when the photovoltaic cell becomes appreciably self-biased, because of the voltage drop developed across the load. Care must be taken to limit this bias to prevent a reduced output signal. As a rule of thumb, this load-voltage drop is kept lower than 50 mV. When measuring high-power emitters, the value of I_L of a 2-by-2-cm photovoltaic cell is capable of reaching the 200-mA level without saturation; therefore at these levels, the input impedance of the ammeter and the value of the calibrated resistor (See Figure 3) must be kept less than 0.25 Ω.

SAMPLE CALCULATION OF DIODE POWER OUTPUT AND QUANTUM EFFICIENCY

Assume the following values:

I_D = emitting diode current = 300 mA

V_F = forward voltage of the emitter = 1.6 volts

I_L = solar cell output signal = 25 mA

λ_p = peak wavelength of the emitter = 0.925 μm

η_{sc} = quantum efficiency of the cell = 0.70 electrons per photon

This material appeared as an article in *Electro-Optical Systems Design*, Vol. 2 No. 7, July 1970.

Then:

η_{em} = emitter quantum efficiency

$$= \left(\frac{I_L}{\eta_{sc}}\right)\left(\frac{1}{I_D}\right) = \left(\frac{25\text{ mA}}{0.7\,\frac{\text{elect}}{\text{photon}}}\right)\left(\frac{1}{300\text{ mA}}\right)$$

= 0.119 photons/electron

η_{em} = 11.9%

$$\text{Optical Power} = P_O = \left(\frac{I_L}{\eta_{sc}}\right)\left(\frac{\text{energy}}{\text{photon}}\right)$$

$$\text{Where energy} = \frac{1.24}{\lambda_p} = \frac{1.24}{0.925} \sim 1.341\text{ eV}$$

$$P_O = \left(\frac{25\text{ mA}}{0.7\,\frac{\text{elect}}{\text{photon}}}\right)\left(1.341\,\frac{\text{eV}}{\text{photon}}\right)$$

$$\text{Power efficiency} = \frac{P_O}{\text{Input Power}}$$

$$= \frac{47.9 \times 10^{-3}\text{ W}}{I_D V_F} = \frac{47.9 \times 10^{-3}\text{ W}}{48 \times 10^{-2}\text{ W}}$$

Power efficiency = 0.0998 = 9.98%

TIL23, TIL24 RELIABILITY DATA

INTRODUCTION

Texas Instruments has long been noted as a quality producer of semiconductor components. The TIL23 and TIL24 solid-state infrared-emitting diodes (IRED's) are high-quality, reliable additions to its line of optoelectronic products. They have been designed as highly reliable, long-life products capable of meeting demanding military and commercial needs. Quality control of these products begins with incoming inspection of raw materials and is continued throughout the manufacturing process as shown in assembly-test flow diagram (Figure 1). Conscientious quality control practiced by the manufacturing organization and monitored at critical steps by the quality control organization assures that the designed reliability will be achieved in the finished product.

Since this product was announced in 1970, some two million device hours of reliability testing have been accumulated on ungraded, unburned-in samples, and additional data is continuously being accumulated. This report summarizes, in graphical form, data on the operating life of TIL23 and TIL24 at 10, 30, and 50 mA at 25°C and 50 mA at 55°C. Results of various mechanical and temperature stress tests are also presented.

OPERATING LIFE TESTS

Room temperature (25°C) life tests were performed at three different current levels: 10 mA, 30 mA and 50 mA. Readings of power output were made with a solar cell in a short-circuit current mode at 0, 168, 500 and 1,000 hours. Forward voltage was read at these intervals and no significant changes were observed. A total of 175 devices were tested at 10 mA or 30 mA with no device evidencing a change in power output greater than −10%. 96 devices were tested at 50 mA with four devices exceeding −20% reduction of power output (−27% worst case). Extended operating life tests at 25°C (4,000 hours) on 300 units have substantiated the extrapolated degradation rates shown in Figures 2, 3, 4, and 5.

STORAGE LIFE TESTS

High-temperature (85°C) storage tests were performed for 1,000 hours on 1386 units with an insignificant change in power output. Only two devices had changes of power output greater than −5% (−13% worst case). No significant changes of forward voltage were observed.

ENVIRONMENTAL TESTS

The tests listed in Figure 6 were performed on samples of the product with no catastrophic failures observed. It should be noted that the test conditions shown are not the ultimate strength of the product but represent the test requirements imposed by our customers. The ultimate strength of these devices is much higher in most cases. Inquiries concerning response to particular requirements should be addressed to your TI sales representative.

TIL23HR, TIL24HR, TIL25HR . . . HIGH-RELIABILITY INFRARED EMITTERS

Texas Instruments now offers the TIL23HR, TIL24HR, and TIL25HR as standard product items to customers requiring extra reliability in their applications. Utilizing the same small ceramic pill package design as LS600 series phototransistor, the TIL23HR, TIL24HR, and TIL25HR are used to provide dependable and reliable infrared sources in military and aerospace applications. The TIL23HR, TIL24HR, and TIL25HR infrared emitters and the complementary TIL601HR thru TIL604HR phototransistors are now available as standard product items. For more information, contact you nearest TI sales representative or Optoelectronic Department Product Marketing.

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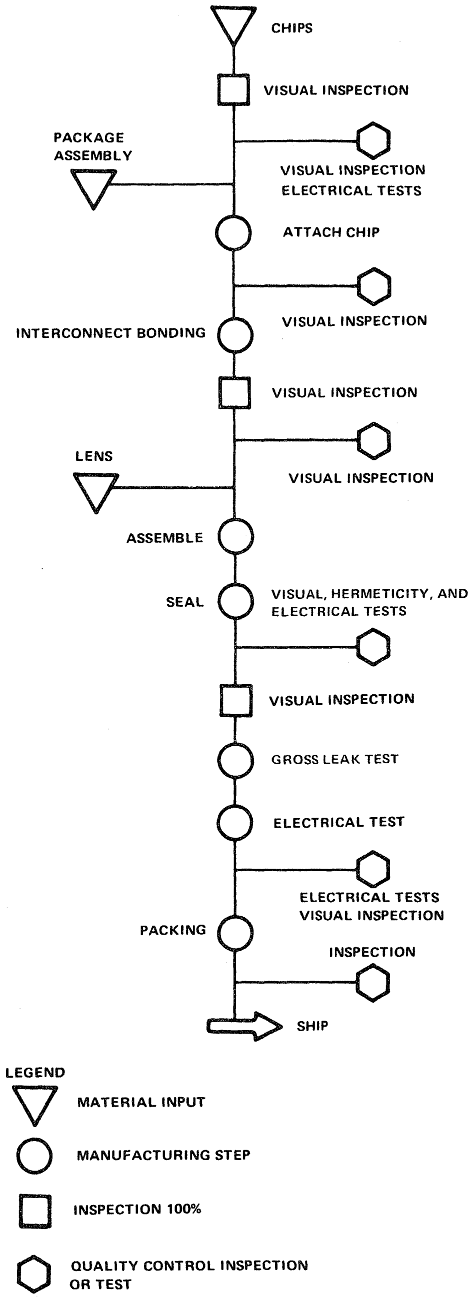

FIGURE 1. TIL23 and TIL24 Infrared-Emitter Flow Diagram

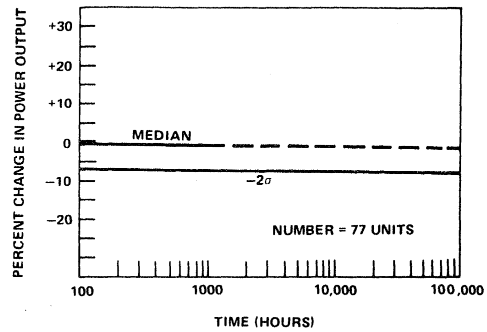

FIGURE 2. Change in Power Output as a Function of Operating Time at I_F = 10 mA, 25°C

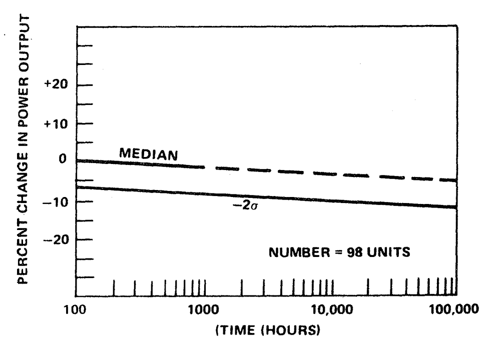

FIGURE 3. Change in Power Output as a Function of Operating Time at I_F = 30 mA, 25°C

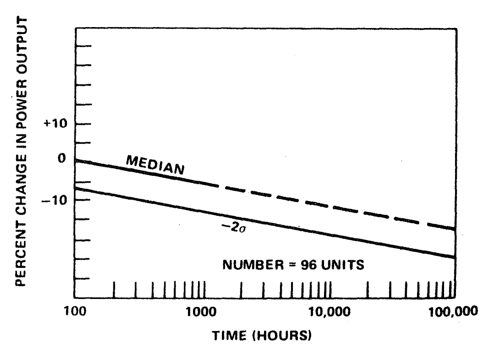

FIGURE 4. Change in Power Output as a Function of Operating Time at I_F = 50 mA, 25°C

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UNITS TESTED	UNIT HOURS	CATASTROPHIC FAILURES	DEGRADATION FAILURES			
			TOTAL	FAILURE RATE IN %/1,000 HOURS		MEAN TIME BETWEEN FAILURES
				60% CONFIDENCE	90% CONFIDENCE	
1384	1,384,000	0	1	0.15	0.28	685,000 HOURS

FIGURE 5. Operating Life at 25°C at 50 mA

MIL-STD-750 Test Method	Test	Quantity Tested	Failures (Catastrophic or Degradation)
1051	Temperature Cycle: 5 Cycles, 30 Minutes, –40°C to +100°C	458	0
1051	Temperature Cycle: 5 Cycles, 30 Minutes, –65°C to +150°C	50	0
1056	Thermal Shock: 5 Cycles, Condition A	50	0
1021	Moisture Resistance	50	0
2016	Shock, Impact: 1500 g, Z_1 Axis, 0.5 milliseconds	830	2
2056	Vibration, Variable Frequency: 20 g	842	1
2006	Constant Acceleration: 20 kg, 1 Min. Z_1	146	0
1071	Hermetic Seal: Test Condition E	390	1

FIGURE 6. Environmental Test Results

Photodetectors

PHOTODETECTORS
QUICK REFERENCE GUIDE

DEVICE	TYPE	LIGHT CURRENT MIN	MAX	@ V	DARK CURRENT MAX	@ V	POWER DISS.	FEATURES
1N5722	Phototransistor	0.5 mA	3 mA	5	25 nA	30	50 mW	EIA-Registered versions of TIL601-TIL604
1N5723	Phototransistor	2 mA	5 mA	5	25 nA	30	50 mW	
1N5724	Phototransistor	4 mA	8 mA	5	25 nA	30	50 mW	
1N5725	Phototransistor	7 mA		5	25 nA	30	50 mW	
LS400	Phototransistor	1 mA		5	25 nA	30	50 mW	Hermetic glass package
LS600	Phototransistor	0.8 mA		5	25 nA	30	50 mW	Pill package
TIL63§	Phototransistor	0.4 mA		5	25 nA	30	50 mW	Low-cost header with epoxy lens. Operating temp. range −40°C to 80°C
TIL64§	Phototransistor	0.4 mA	1.6 mA	5	25 nA	30	50 mW	
TIL65§	Phototransistor	1 mA	4 mA	5	25 nA	30	50 mW	
TIL66§	Phototransistor	2.5 mA	10 mA	5	25 nA	30	50 mW	
TIL67§	Phototransistor	6 mA		5	25 nA	30	50 mW	
TIL78	Phototransistor	1 mA		5	25 nA	30	50 mW	Low-cost epoxy package
TIL81	As Phototransistor	5 mA		5	100 nA	10	250 mW	TO-18 package with narrow field of view
	As Photodiode	170 μA Typ		0–50	10 nA	30	250 mW	
TIL99	As Phototransistor	1 mA		5	100 nA	10	250 mW	Similar to TIL81 except flat lens
	As Photodiode	40 μA Typ		0–50	10 nA	10	250 mW	
TIL401	Phototransistor	0.5 mA	3 mA	5	25 nA	30	50 mW	Glass, hermetically sealed
TIL402	Phototransistor	2 mA	6 mA	5	25 nA	30	50 mW	
TIL403	Phototransistor	5 mA	10 mA	5	25 nA	30	50 mW	
TIL404	Phototransistor	8 mA	16 mA	5	25 nA	30	50 mW	
TIL405	Phototransistor	10 mA	20 mA	5	25 nA	30	50 mW	
TIL406	Phototransistor	15 mA		5	25 nA	30	50 mW	
TIL601†	Phototransistor	0.5 mA	3 mA	5	25 nA	30	50 mW	Pill package designed for mounting on double-sided printed board.
TIL602†	Phototransistor	2 mA	5 mA	5	25 nA	30	50 mW	
TIL603†	Phototransistor	4 mA	8 mA	5	25 nA	30	50 mW	
TIL604†	Phototransistor	7 mA		5	25 nA	30	50 mW	
TIL605	Phototransistor	0.5 mA	3 mA	5	25 nA	30	50 mW	Same as TIL601–TIL604 except wider field of view
TIL606	Phototransistor	2 mA	5 mA	5	25 nA	30	50 mW	
TIL607	Phototransistor	4 mA	8 mA	5	25 nA	30	50 mW	
TIL608	Phototransistor	7 mA		5	25 nA	30	50 mW	
TIL609	Phototransistor	0.5 mA	3 mA	5	25 nA	30	50 mW	Coaxial package designed for mounting on single-sided printed circuit board
TIL610	Phototransistor	2 mA	5 mA	5	25 nA	30	50 mW	
TIL611	Phototransistor	4 mA	8 mA	5	25 nA	30	50 mW	
TIL612	Phototransistor	7 mA		5	25 nA	30	50 mW	
TIL613	Phototransistor	0.5 mA	3 mA	5	25 nA	30	50 mW	Same as TIL609–TIL612 except wider field of view
TIL614	Phototransistor	2 mA	5 mA	5	25 nA	30	50 mW	
TIL615	Phototransistor	4 mA	8 mA	5	25 nA	30	50 mW	
TIL616	Phototransistor	7 mA		5	25 nA	30	50 mW	
TIL621	Phototransistor	1.5 mA		5	50 nA	30	50 mW	Single element
TIL622	Phototransistor	1.5 mA		5	50 nA	30	50 mW‡	2-element array
TIL623	Phototransistor	1.5 mA		5	50 nA	30	50 mW‡	3-element array
TIL624	Phototransistor	1.5 mA		5	50 nA	30	50 mW‡	4-element array
TIL625	Phototransistor	1.5 mA		5	50 nA	30	50 mW‡	5-element array
TIL626	Phototransistor	1.5 mA		5	50 nA	30	50 mW‡	6-element array
TIL627	Phototransistor	1.5 mA		5	50 nA	30	50 mW‡	7-element array
TIL628	Phototransistor	1.5 mA		5	50 nA	30	50 mW‡	8-element array
TIL629	Phototransistor	1.5 mA		5	50 nA	30	50 mW‡	9-element array
TIL630	Phototransistor	1.5 mA		5	50 nA	30	50 mW‡	10-element array

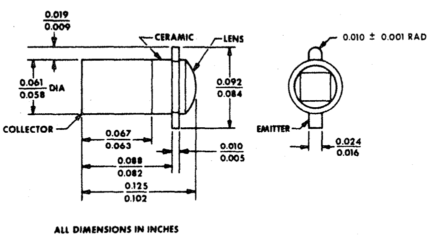
†High-reliability versions (TIL601HR thru TIL604HR) are also available.
‡Each element.
§Not recommended for new design.
For additional photodetectors, see *Special Electro-optical Components* section of this book.

BULLETIN NO. DL-S 7411689, MARCH 1972–REVISED NOVEMBER 1974

JEDEC-REGISTERED VERSIONS OF TIL601 THRU TIL604

- **Recommended for Application in Character Recognition, Tape and Card Readers, Velocity Indicators, and Encoders**
- **Unique Package Design Allows for Assembly into Printed Circuit Boards**

*mechanical data



FOUR TIMES ACTUAL SIZE

*absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Emitter Voltage	50 V
Emitter-Collector Voltage	7 V
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 1)	50 mW
Operating Case Temperature Range	–65°C to 125°C
Storage Temperature Range	–65°C to 150°C
Soldering Temperature (3 minutes)	240°C

*electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TYPE	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 100 µA, E_e = 0	ALL	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	I_E = 100 µA, E_e = 0	ALL	7			V
I_D	Dark Current	V_{CE} = 30 V, E_e = 0	ALL			25	nA
		V_{CE} = 30 V, E_e = 0, T_C = 100°C	ALL		1		µA
I_L	Light Current	V_{CE} = 5 V, E_e = 20 mW/cm², See Note 2	1N5722	0.5		3	mA
			1N5723	2		5	
			1N5724	4		8	
			1N5725	7			
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 0.4 mA, E_e = 20 mW/cm², See Note 2	ALL		0.15		V

NOTES: 1. Derate linearly to 125°C at the rate of 0.5 mW/°C.
2. Irradiance (E_e) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

*JEDEC registered data. This data sheet contains all applicable JEDEC registered data in effect at the time of publication.

TEXAS INSTRUMENTS
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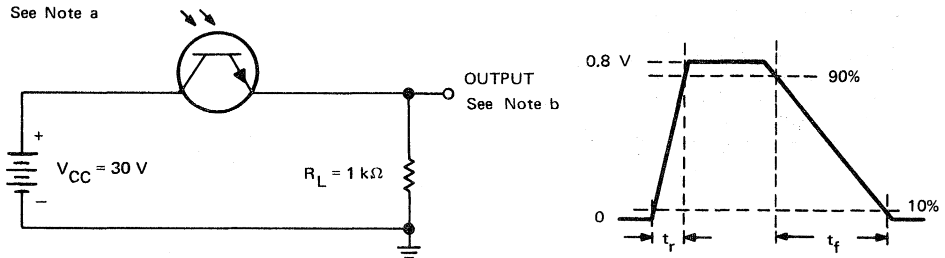
TYPES 1N5722 THRU 1N5725
N-P-N PLANAR SILICON PHOTOTRANSISTORS

*switching characteristics at 25° C case temperature

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_r Rise Time	$V_{CC} = 30$ V, $I_L = 800$ μA,		1.5	2.5	μs
t_f Fall Time	$R_L = 1$ kΩ, See Figure 1		15	25	

*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 1

NOTES: a. Input irradiance is supplied by a pulsed xenon bulb source. Incident irradiation is adjusted for $I_L = 800$ μA.

b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 25$ ns, $R_{in} \geqslant 1$ MΩ, $C_{in} \leqslant 20$ pF.

*JEDEC registered data

TYPICAL CHARACTERISTICS

COUPLING CHARACTERISTICS
vs
OF 1N5723 WITH TIL23 OR TIL24

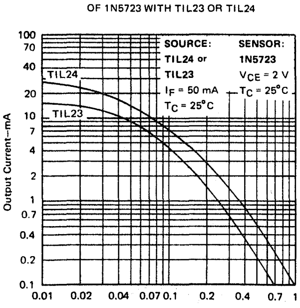


FIGURE 2

RELATIVE OUTPUT
vs
CASE TEMPERATURE OF SOURCE AND SENSOR

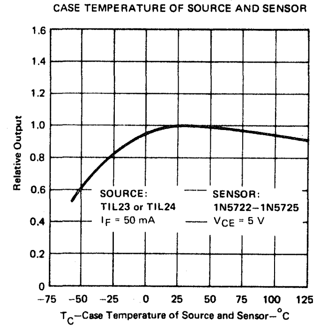


FIGURE 3

NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

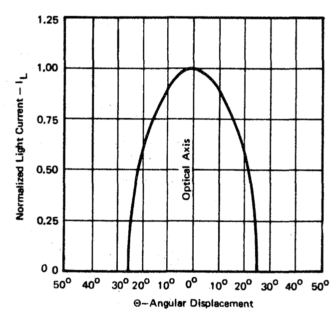


FIGURE 4

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TYPICAL CHARACTERISTICS

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

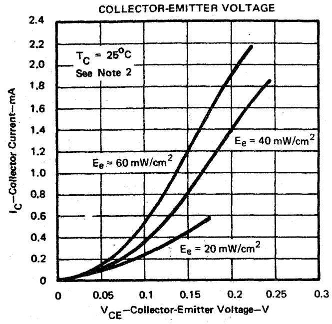

FIGURE 5

1N5723
COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

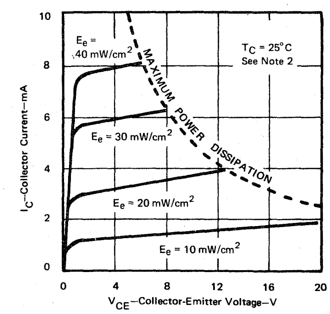

FIGURE 6

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
IRRADIANCE

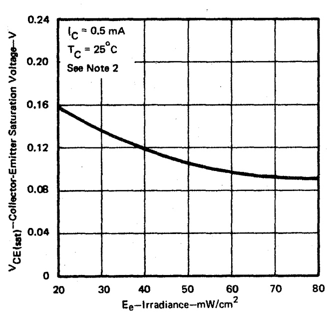

FIGURE 7

1N5723
COLLECTOR CURRENT
vs
IRRADIANCE

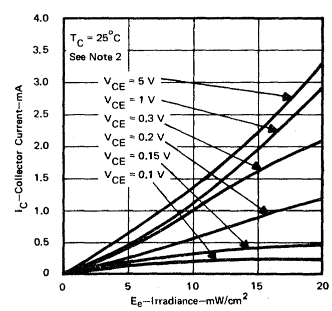

FIGURE 8

DARK CURRENT
vs
CASE TEMPERATURE

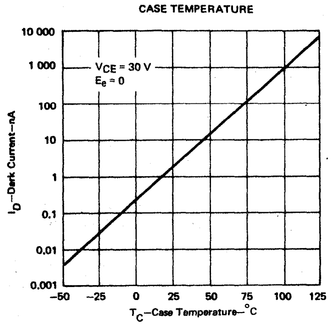

FIGURE 9

RELATIVE OUTPUT
vs
MODULATION FREQUENCY

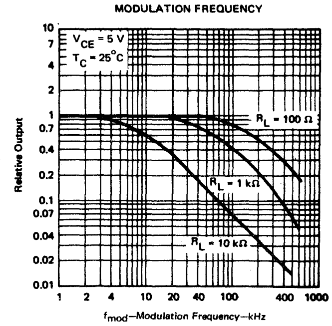

FIGURE 10

NOTE 2: Irradiance (E_e) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

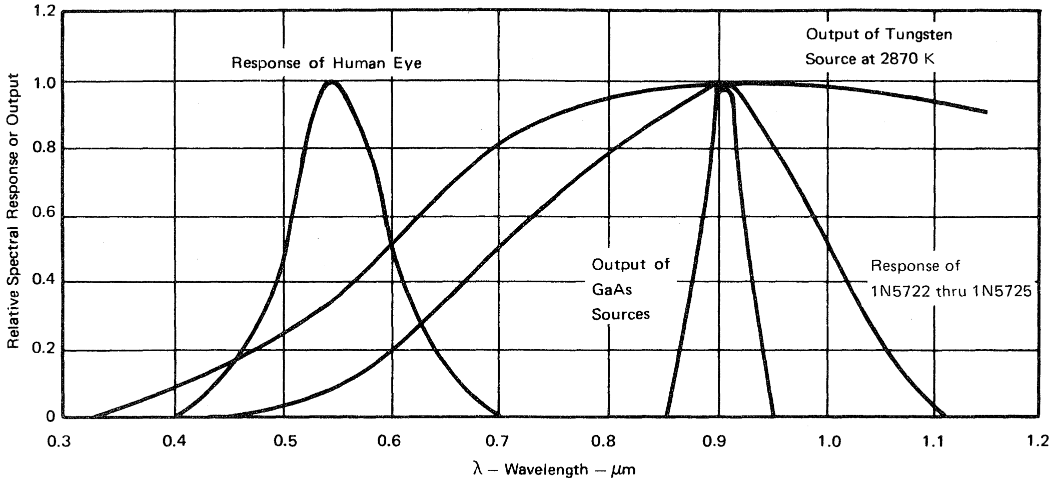

FIGURE 11

TEXAS INSTRUMENTS CUSTOMIZED OPTOELECTRONIC ARRAYS

The 1N5722 through 1N5725 series is available mounted in printed circuit boards for custom-designed array or matrix applications. The array is a complete unit, without the problems associated with small, difficult-to-handle components. These arrays can be designed for punched-card or tape readers, position indicators, pattern and character recognition, shaft encoders, and many other special applications.

Texas Instruments custom-array techniques offer many advantages:

- The arrays are pre-assembled and tested, ready for installation.
- Custom arrays can be manufactured in almost any configuration to allow maximum design flexibility.
- Sensitivity across an entire array will be matched to within 50%.
- GaAs sources can be furnished to give complete solid-state matched sets for specific applications.
- Arrays with components firmly soldered into place on both sides of a printed circuit board are more rugged than individually wired sensing devices.

Specifying optoelectronic arrays is easy; all that is required is a print of the array and the desired specifications.

TI sales engineers will assist in developing specifications for special applications.

Standard card-reader and tape-reader arrays are available.

TEXAS INSTRUMENTS
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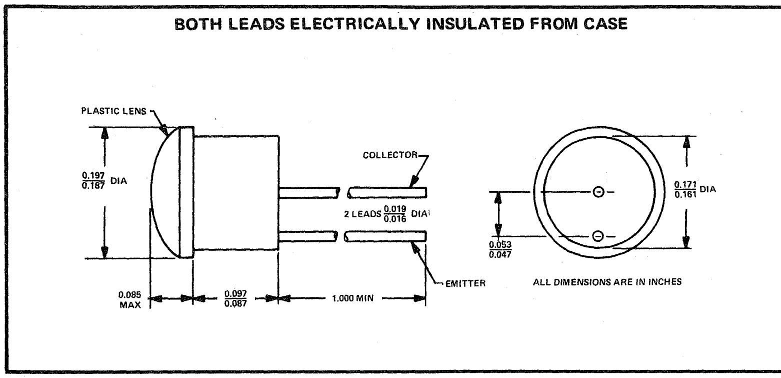
PRINTED IN U S A

BULLETIN NO. DL-S 7411291, DECEMBER 1969—REVISED NOVEMBER 1974

NOT RECOMMENDED FOR NEW DESIGN

FOR NEW DESIGN, USE TIL81

mechanical data



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Emitter Voltage	50 V
Emitter-Collector Voltage	7 V
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	50 mW
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 100°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TYPE	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$, $E_e = 0$	ALL	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 100\ \mu A$, $E_e = 0$	ALL	7			V
I_D	Dark Current	$V_{CE} = 30$ V, $E_e = 0$	ALL			25	nA
		$V_{CE} = 30$ V, $E_e = 0$, $T_A = 80°C$	ALL		0.5		μA
I_L	Light Current	$V_{CE} = 5$ V, $E_e = 20\ mW/cm^2$, See Note 2	TIL63	0.4			mA
			TIL64	0.4		1.6	
			TIL65	1		4	
			TIL66	2.5		10	
			TIL67	6			
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 0.4$ mA, $E_e = 20\ mW/cm^2$, See Note 2	ALL		0.15		V

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.91 mW/°C.
2. Irradiance (E_e) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

TEXAS INSTRUMENTS
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switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_r	Rise Time	$V_{CC} = 30$ V, $I_L = 800\ \mu A$, $R_L = 1\ k\Omega$, See Figure 1	8	μs
t_f	Fall Time		6	

PARAMETER MEASUREMENT INFORMATION

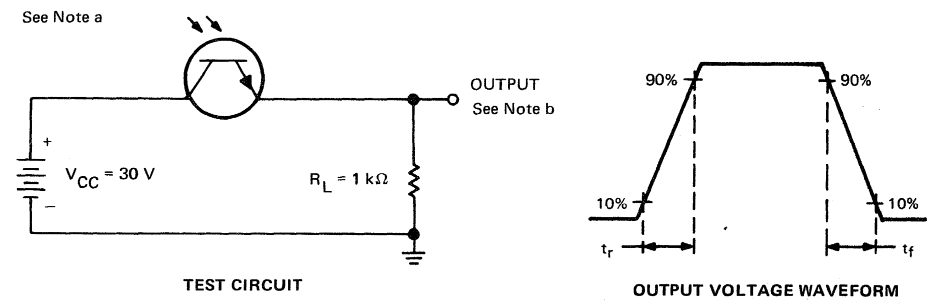

FIGURE 1

NOTES: a. Input irradiance is supplied by a pulsed gallium arsenide infrared emitter with rise and fall times of less than 50 ns. Incident irradiation is adjusted for $I_L = 800\ \mu A$.
b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 25$ ns, $R_{in} \geqslant 1\ M\Omega$, $C_{in} \leqslant 20$ pF.

TYPICAL APPLICATION DATA

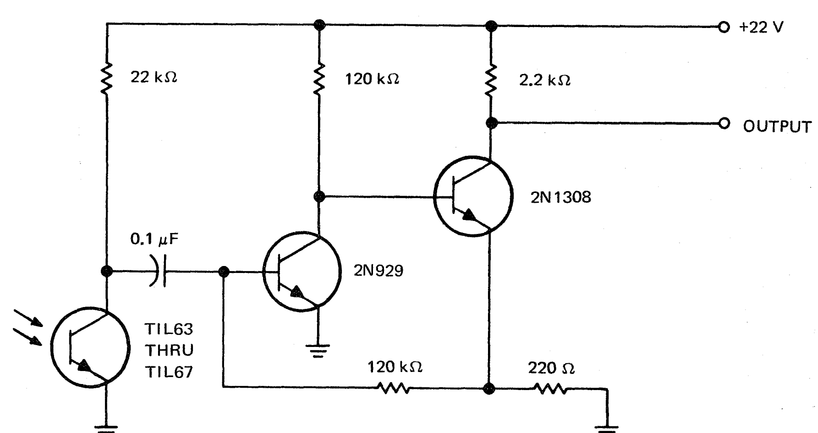

FIGURE 2—LIGHT PULSE DETECTOR

1174

TYPICAL CHARACTERISTICS

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

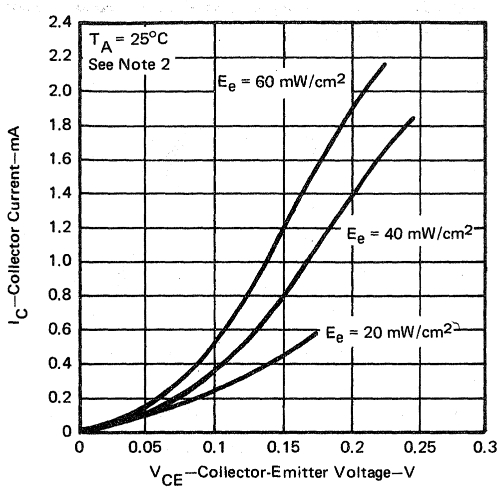

FIGURE 3

TIL65
COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

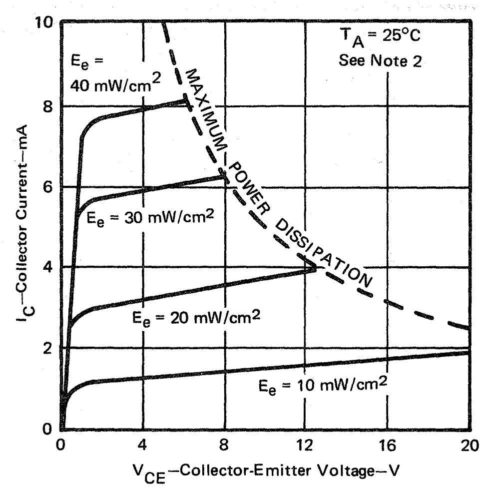

FIGURE 4

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
IRRADIANCE

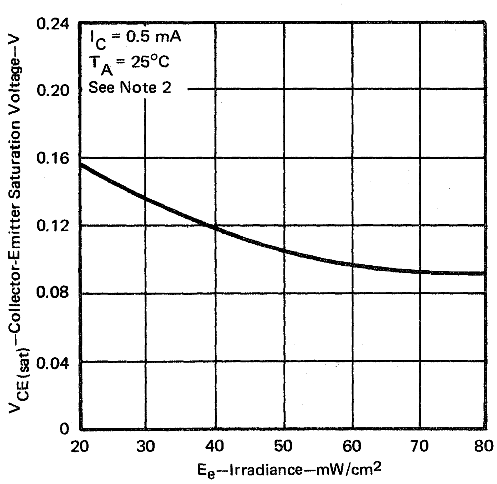

FIGURE 5

DARK CURRENT
vs
FREE-AIR TEMPERATURE

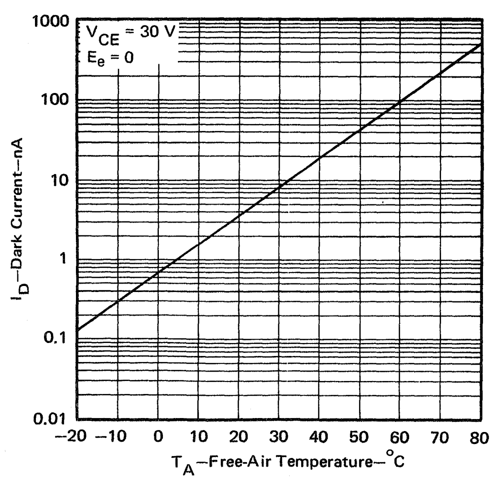

FIGURE 6

NOTE: 2. Irradiance (E_e) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

4

4

TYPICAL CHARACTERISTICS

RELATIVE OUTPUT
vs
MODULATION FREQUENCY

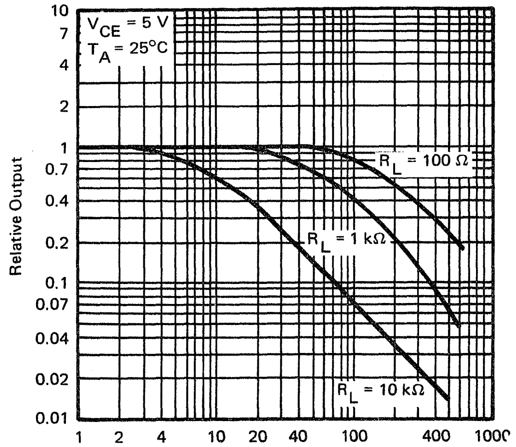

FIGURE 7

NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

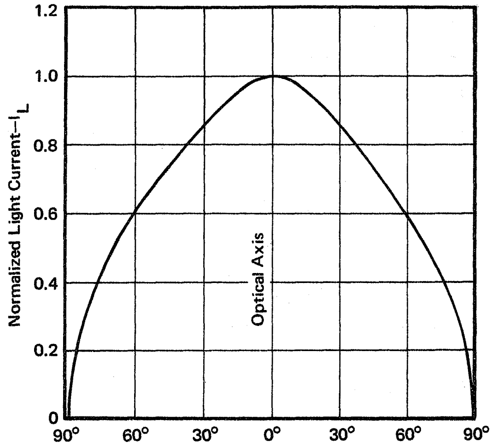

FIGURE 8

RELATIVE SPECTRAL CHARACTERISTICS

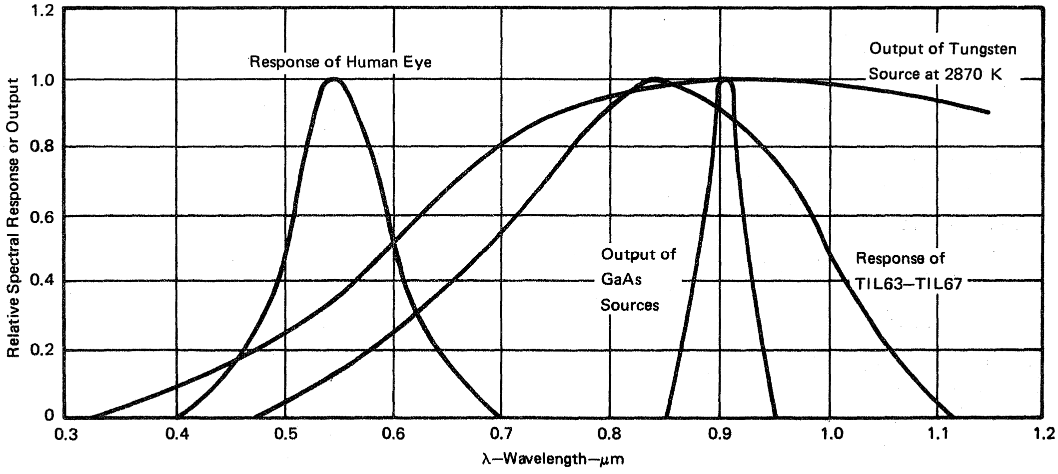

FIGURE 9

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PRINTED IN U.S.A.

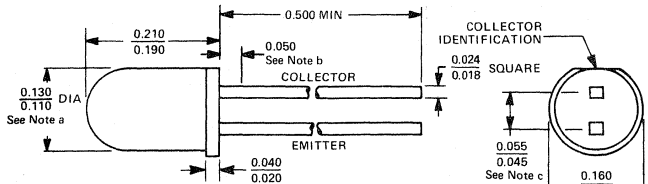
1174

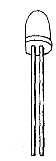
BULLETIN NO. DL-S 7611549, SEPTEMBER 1971—REVISED MARCH 1976

- Designed for Automatic or Hand Insertion in Sockets or PC Boards
- Recommended for Industrial Applications Requiring Low-Cost Discrete Phototransistors
- Spectrally and Mechanically Matched with TIL32 IR Emitter.

mechanical data

This device has a clear molded epoxy body.





NOTES: a. This diameter is measured 0.005 inch from the shoulder.
b. Within this zone the package contour is not controlled.
c. Lead spacing is measured where the leads emerge from the package.
d. All dimensions are in inches.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Emitter Voltage	50 V
Emitter-Collector Voltage	7 V
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	50 mW
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 85°C
Lead Temperature 1/16 Inch from Case for 5 Seconds	240°C

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

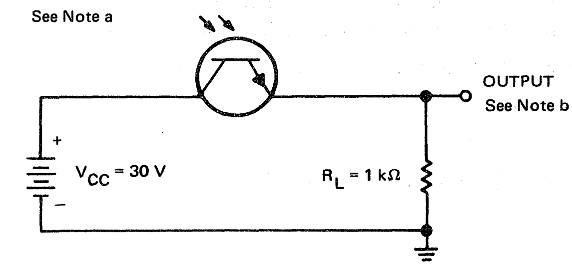
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$, $E_e = 0$		50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 100\ \mu A$, $E_e = 0$		7			V
I_D	Dark Current	$V_{CE} = 30\ V$, $E_e = 0$				25	nA
		$V_{CE} = 30\ V$, $E_e = 0$, $T_A = 80°C$				1	μA
I_L	Light Current	$V_{CE} = 5\ V$, $E_e = 20\ mW/cm^2$	See Note 2	1	7		mA
		$V_{CE} = 5\ V$, $E_e = 2\ mW/cm^2$			0.5		
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 2\ mA$, $E_e = 20\ mW/cm^2$	See Note 2		0.4		V

switching characteristics at 25°C free-air temperature

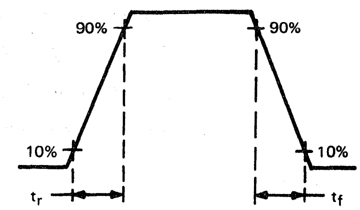
PARAMETER		TEST CONDITIONS	TYP	UNIT
t_r	Rise Time	$V_{CC} = 30\ V$, $I_L = 800\ \mu A$,	8	μs
t_f	Fall Time	$R_L = 1\ k\Omega$, See Figure 1	6	

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.91 mW/°C.
2. Irradiance (E_e) is the radiant ppwer per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



OUTPUT VOLTAGE WAVEFORM

FIGURE 1

NOTES: a. Input irradiance is supplied by a pulsed gallium arsenide infrared emitter with rise and fall times of less than 50 ns. Incident irradiation is adjusted for I_L = 800 μA.

b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 25$ ns, $R_{in} \geqslant 1$ MΩ, $C_{in} \leqslant 20$ pF.

TYPICAL CHARACTERISTICS

NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

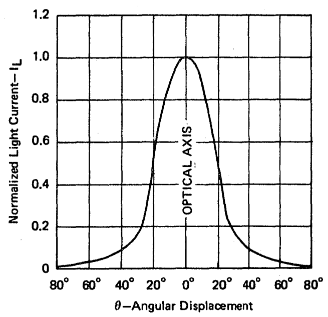


FIGURE 1

DARK CURRENT
vs
FREE-AIR TEMPERATURE

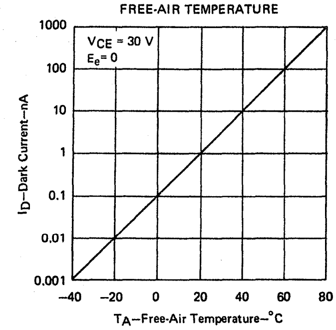


FIGURE 2

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
IRRADIANCE

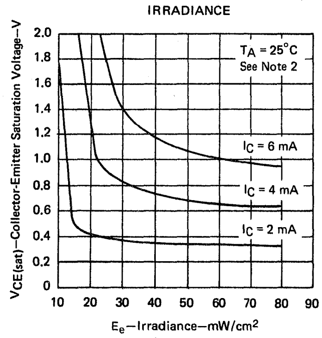


FIGURE 3

COUPLING CHARACTERISTICS
OF
TIL32 WITH TIL78

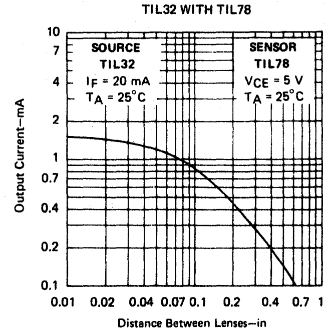


FIGURE 4

NOTE 2: Irradiance (E_e) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

TEXAS INSTRUMENTS
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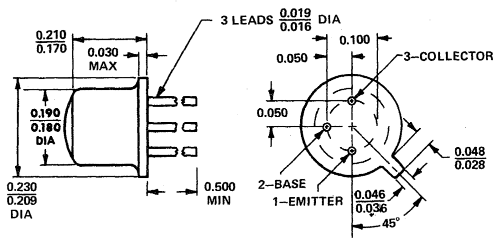
PRINTED IN U.S.A. 1174

BULLETIN NO. DL-S 7611688, MARCH 1972—REVISED MARCH 1976

- Recommended for Application in Character Recognition, Tape and Card Readers, Velocity Indicators, and Encoders
- Spectrally and Mechanically Matched with TIL31 IR Emitter
- Glass-to-Metal-Seal Header
- Base Contact Externally Available
- Saturation Level Directly Compatible with Most TTL/DTL

mechanical data

The device is in a hermetically sealed package with glass window. The outline of the TIL81 is similar to TO-18 except for the window. All TO-18 registration notes also apply to this outline

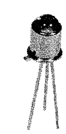


THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE

MAXIMUM WINDOW EXTENSION FROM TOP OF CASE IS 0.070, MINIMUM DIAMETER IS 0.125

THE LENS IS CORNING 7052 GLASS (OR EQUIVALENT)

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	50 V
Collector-Emitter Voltage	30 V
Emitter-Base Voltage	7 V
Emitter-Collector Voltage	7 V
Continuous Collector Current	50 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	250 mW
Operating Free-Air Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

NOTE 1: Derate linearly to 125°C free-air temperature at the rate of 2.5 mW/°C.

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electrical characteristics at 25°C free-air temperature (unless otherwise noted)

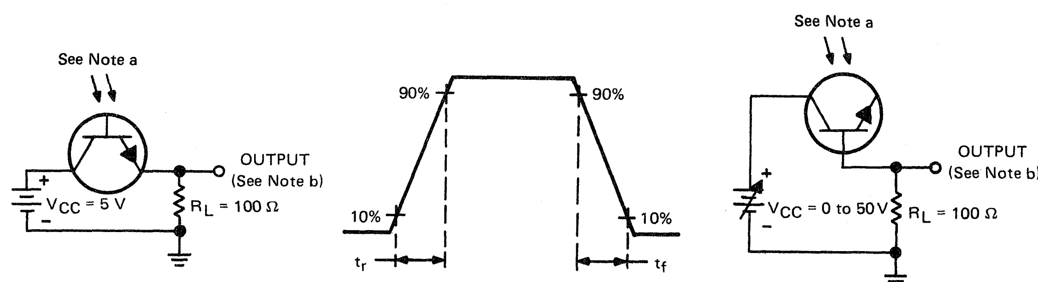
PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage		$I_C = 100\ \mu A$, $I_E = 0$, $E_e = 0$	50			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage		$I_C = 100\ \mu A$, $I_B = 0$, $E_e = 0$	30			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage		$I_E = 100\ \mu A$, $I_C = 0$, $E_e = 0$	7			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage		$I_E = 100\ \mu A$, $I_B = 0$, $E_e = 0$	7			V
I_D	Dark Current	Phototransistor Operation	$V_{CE} = 10$ V, $I_B = 0$, $E_e = 0$			0.1	µA
			$V_{CE} = 10$ V, $I_B = 0$, $E_e = 0$, $T_A = 100°C$		20		µA
		Photodiode Operation	$V_{CB} = 10$ V, $I_E = 0$, $E_e = 0$			0.01	µA
I_L	Light Current	Phototransistor Operation	$V_{CE} = 5$ V, $I_B = 0$, $E_e = 5\ mW/cm^2$, See Note 2	5	22		mA
		Photodiode Operation	$V_{CB} = 0$ to 50 V, $I_E = 0$, $E_e = 20\ mW/cm^2$, See Note 2		170		µA
h_{FE}	Static Forward Current Transfer Ratio		$V_{CE} = 5$ V, $I_C = 1$ mA, $E_e = 0$		200		
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage		$I_C = 2$ mA, $I_B = 0$, $E_e = 20\ mW/cm^2$, See Note 2		0.2		V

NOTE 2: Irradiance (E_e) is the radiant power per unit area incident upon a surface. For these measurements the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

switching characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	TYPICAL	UNIT
t_r	Rise Time	Phototransistor Operation	$V_{CC} = 5$ V, $I_L = 800\ \mu A$, $R_L = 100\ \Omega$, See Test Circuit A of Figure 1	8	µs
t_f	Fall Time			6	µs
t_r	Rise Time	Photodiode Operation	$V_{CC} = 0$ to 50 V, $I_L = 60\ \mu A$, $R_L = 100\ \Omega$, See Test Circuit B of Figure 1	350	ns
t_f	Fall Time			500	ns

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT A
PHOTOTRANSISTOR OPERATION

VOLTAGE WAVEFORM

TEST CIRCUIT B
PHOTODIODE OPERATION

NOTES: a. Input irradiance is supplied by a pulsed gallium arsenide infrared emitter with rise and fall times less than 50 ns. Incident irradiation is adjusted for specified I_L.

b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 25$ ns, $R_{in} \geq 1\ M\Omega$, $C_{in} \leq 20$ pF.

FIGURE 1

4

TYPICAL CHARACTERISTICS

NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

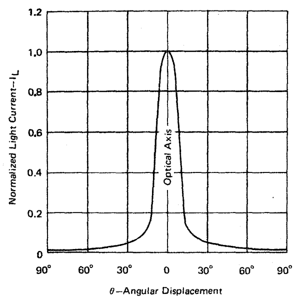


FIGURE 2

COUPLING CHARACTERISTICS
OF
TIL31 WITH TIL81

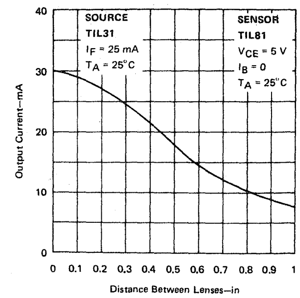


FIGURE 3

COLLECTOR CURRENT
(PHOTOTRANSISTOR OPERATION)
vs
IRRADIANCE

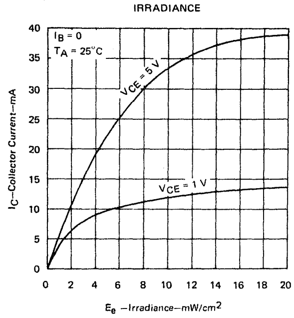


FIGURE 4

COLLECTOR CURRENT
(PHOTODIODE OPERATION)
vs
COLLECTOR-EMITTER VOLTAGE

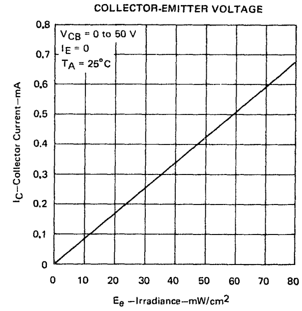


FIGURE 5

COLLECTOR CURRENT
(PHOTOTRANSISTOR OPERATION)
vs
COLLECTOR-EMITTER VOLTAGE

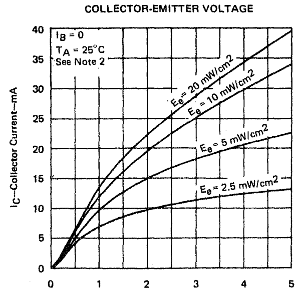


FIGURE 6

COLLECTOR-EMITTER
SATURATION VOLTAGE
vs
COLLECTOR CURRENT

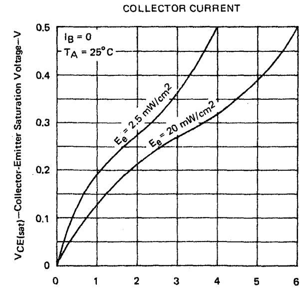


FIGURE 7

NOTE 2: Irradiance (E_e) is the radiant power per unit area incident upon a surface. For these measurements the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

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TYPICAL CHARACTERISTICS

RELATIVE OUTPUT
(PHOTOTRANSISTOR OPERATION)
vs
MODULATION FREQUENCY

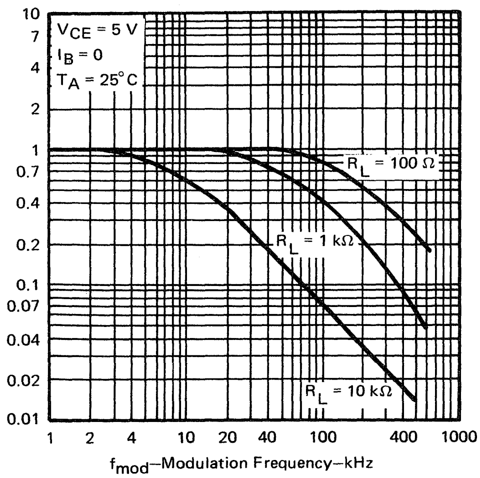

FIGURE 8

NORMALIZED DARK CURRENT
vs
FREE-AIR TEMPERATURE

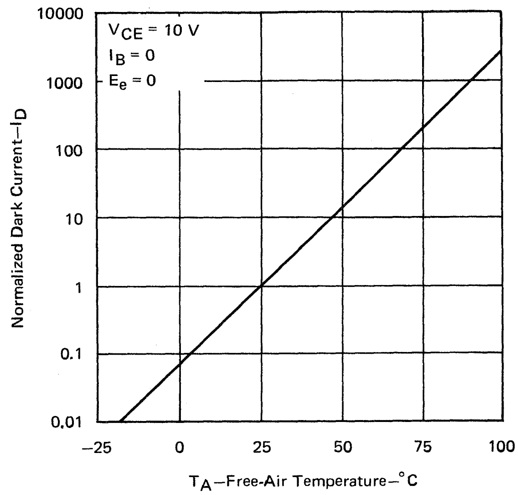

FIGURE 9

RELATIVE SPECTRAL CHARACTERISTICS

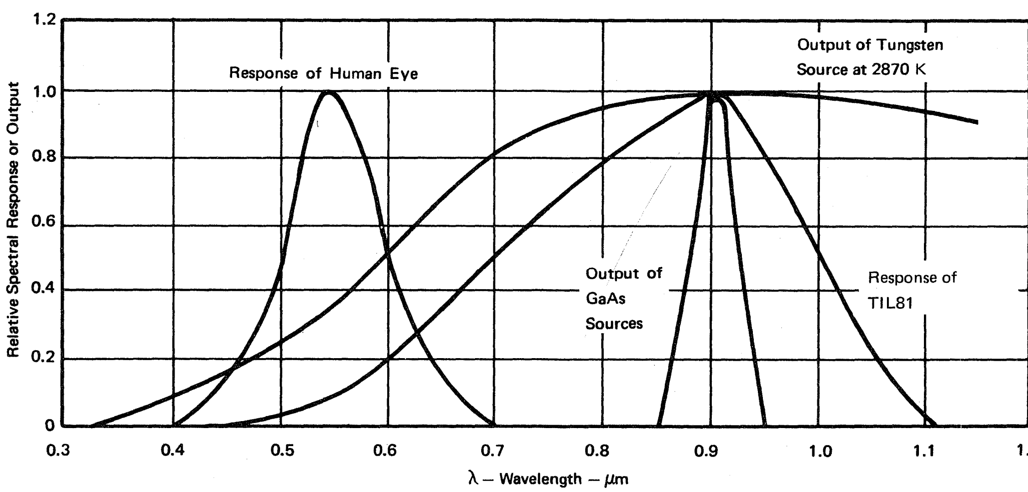

FIGURE 10

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PRINTED IN U.S.A. 1174

BULLETIN NO. DL-S 7612218, NOVEMBER 1974—REVISED MARCH 1976

FOR WIDE-ANGLE VIEWING APPLICATIONS

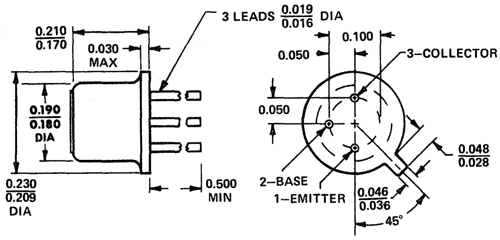
- Recommended for Application in Character Recognition, Tape and Card Readers, Velocity Indicators, and Encoders
- Spectrally and Mechanically Matched with TIL31 IR Emitter
- Glass-to-Metal-Seal Header
- Base Connection Externally Available
- Saturation Level Directly Compatible with Most TTL/DTL

4

mechanical data

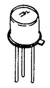
The device is in a hermetically sealed package with glass window. The outline of the TIL99 is similar to TO-18 except for the window. All TO-18 registration notes also apply to this outline.

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



MAXIMUM WINDOW EXTENSION FROM TOP OF CASE IS 0.010
MINIMUM DIAMETER IS 0.140

THE WINDOW IS CORNING 7052 GLASS (OR EQUIVALENT)



All dimensions are in inches unless otherwise specified.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Base Voltage	50 V
Collector-Emitter Voltage	30 V
Emitter-Base Voltage	7 V
Emitter-Collector Voltage	7 V
Continuous Collector Current	50 mA
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 1)	250 mW
Operating Free-Air Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

NOTE 1: Derate linearly to 125°C free-air temperature at the rate of 2.5 mW/°C.

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electrical characteristics at 25°C free-air temperature (unless otherwise noted)

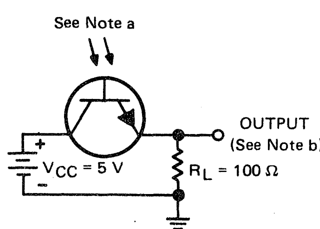
PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage		$I_C = 100\ \mu A$, $I_E = 0$, $E_e = 0$	50			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage		$I_C = 100\ \mu A$, $I_B = 0$, $E_e = 0$	30			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage		$I_E = 100\ \mu A$, $I_C = 0$, $E_e = 0$	7			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage		$I_E = 100\ \mu A$, $I_B = 0$, $E_e = 0$	7			V
I_D	Dark Current	Phototransistor Operation	$V_{CE} = 10\ V$, $I_B = 0$, $E_e = 0$			0.1	μA
			$V_{CE} = 10\ V$, $I_B = 0$, $E_e = 0$, $T_A = 100°C$		20		
		Photodiode Operation	$V_{CE} = 10\ V$, $I_E = 0$, $E_e = 0$			0.01	μA
I_L	Light Current	Phototransistor Operation	$V_{CE} = 5\ V$, $I_B = 0$, $E_e = 20\ mW/cm^2$, See Note 2	1	5		mA
		Photodiode Operation	$V_{CB} = 0$ to $50\ V$, $I_E = 0$, $E_e = 20\ mW/cm^2$, See Note 2		40		μA
h_{FE}	Static Forward Current Transfer Ratio		$V_{CE} = 5\ V$, $I_C = 1\ mA$, $E_e = 0$		200		
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage		$I_C = 0.4\ mA$, $I_B = 0$, $E_e = 20\ mW/cm^2$, See Note 2		0.2		V

NOTE 2: Irradiance (E_e) is the radiant power per unit area incident upon a surface. For these measurements the source is an unfiltered tungsten linear-filament lamp operating at a color temperature at 2870 K.

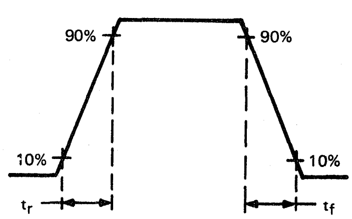
switching characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	TYPICAL	UNIT
t_r	Rise Time	Phototransistor Operation	$V_{CC} = 5\ V$, $I_L = 800\ \mu A$, $R_L = 100\ \Omega$, See Test Circuit A of Figure 1	8	μs
t_f	Fall Time			6	
t_r	Rise Time	Photodiode Operation	$V_{CC} = 0$ to $50\ V$, $I_L = 60\ \mu A$, $R_L = 100\ \Omega$, See Test Circuit B of Figure 1	350	ns
t_f	Fall Time			500	

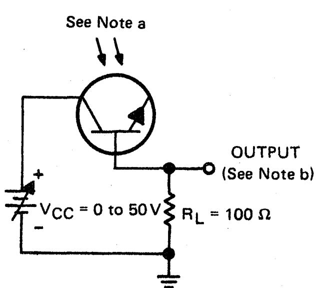
PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT A
PHOTOTRANSISTOR OPERATION



VOLTAGE WAVEFORM



TEST CIRCUIT B
PHOTODIODE OPERATION

NOTES: a. Input irradiance is supplied by a pulsed gallium arsenide radiant-energy source with rise and fall times less than 50 ns. Incident irradiation is adjusted for specified I_L.
b. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 25$ ns, $R_{in} \geq 1\ M\Omega$, $C_{in} \leq 20$ pF.

FIGURE 1

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INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

PRINTED IN U.S.A. 1174

BULLETIN NO. DL-S 7412217, NOVEMBER 1974

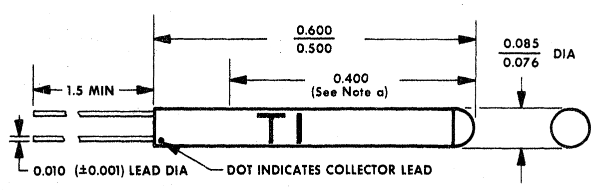
DESIGNED FOR APPLICATIONS IN CHARACTER RECOGNITION TAPE-READOUT, PHOTO SWITCHING, PROPORTIONAL CONTROL, AND DIFFERENTIAL DETECTION

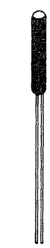
- Fast Switching Times
- Collector-Emitter Breakdown Voltage . . . 50 V Min

4

mechanical data

Each device is in a hard glass, hermetically sealed package with a dome-shaped lens. Unit weight is approximately 0.1 gram.





NOTES: a. Within this zone, body diameter is 0.079 ± 0.003
b. All dimensions are in inches.

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Emitter Voltage	50 V
Emitter-Collector Voltage	6 V
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 1)	50 mW
Operating Case Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 100 μA, E_e = 0		50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	I_E = 100 μA, E_e = 0		6			V
I_D	Dark Current	V_{CE} = 30 V, E_e = 0			10	25	nA
		V_{CE} = 30 V, E_e = 0, T_C = 100°C			10	30	μA
I_L	Light Current	V_{CE} = 5 V, E_e = 9 mW/cm^2, See Note 2	LS400	1			mA
			TIL401	0.5		3	
			TIL402	2		6	
			TIL403	5		10	
			TIL404	8		16	
			TIL405	10		20	
			TIL406	15			
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 0.4 mA, E_e = 9 mW/cm^2, See Note 2			0.3		V

NOTES: 1. Derate linearly to 125°C case temperature at the rate of 0.5 mW/°C.
2. Irradiance (E_e) is the radiant power per unit area incident upon a surface. For this measurement the source is a tungsten-filament bulb. The wavelength is 0.7 to 1.0 μm determined by a Corning CS7-69 filter.

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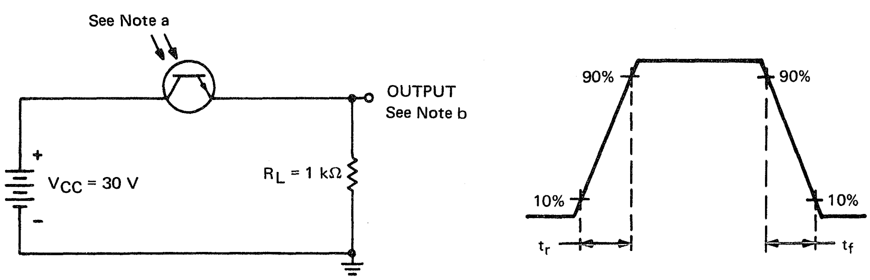
TYPES LS400, TIL401 THRU TIL406
N-P-N PLANAR SILICON PHOTOTRANSISTORS

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_r	Rise Time	V_{CC} = 30 V, I_L = 400 μA,	8	μs
t_f	Fall Time	R_L = 1 kΩ, See Figure 1	6	μs

4

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 1

NOTES: a. Input irradiance is supplied by a pulsed gallium arsenide infrared emitter with rise and fall times of less than 50 ns. Incident irradiation is adjusted for I_L = 400 μA.

b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant$ 25 ns, $R_{in} \geqslant$ 1 MΩ, $C_{in} \leqslant$ 20 pF.

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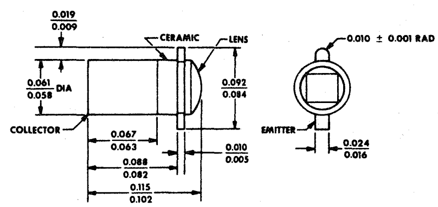
PRINTED IN U.S.A. 1174

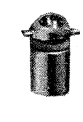
- Designed for High-Density Read Out
- Improved and Repackaged Versions of LS600

mechanical data

LS600, TIL601 THRU TIL604

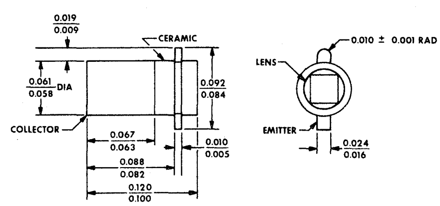


ALL DIMENSIONS IN INCHES

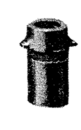


FOUR TIMES ACTUAL SIZE

TIL605 THRU TIL608

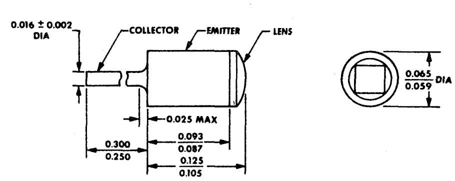


ALL DIMENSIONS IN INCHES



FOUR TIMES ACTUAL SIZE

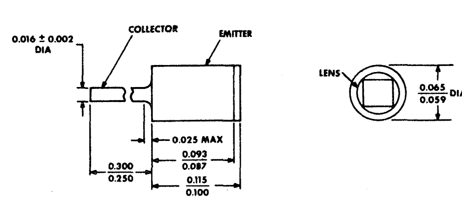
TIL609 THRU TIL612



ALL DIMENSIONS IN INCHES

FOUR TIMES ACTUAL SIZE

TIL613 THRU TIL616



ALL DIMENSIONS IN INCHES

FOUR TIMES ACTUAL SIZE

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Collector-Emitter Voltage	50 V
Emitter-Collector Voltage	7 V
Continuous Device Dissipation at (or below) 25°C Case Temperature (See Note 1)	50 mW
Operating Case Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Soldering Temperature (3 minutes)	240°C

electrical characteristics at 25°C case temperature (unless otherwise noted)

4

PARAMETER		TEST CONDITIONS	TYPE	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$, $E_e = 0$	ALL	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 100\ \mu A$, $E_e = 0$	ALL	7			V
I_D	Dark Current	$V_{CE} = 30\ V$, $E_e = 0$	ALL			25	nA
		$V_{CE} = 30\ V$, $E_e = 0$, $T_C = 100°C$	ALL		3		μA
I_L	Light Current	$V_{CE} = 5\ V$, $E_e = 20\ mW/cm^2$, See Note 2	LS600	0.8			mA
			TIL601 TIL605 TIL609 TIL613	0.5		3	mA
			TIL602 TIL606 TIL610 TIL614	2		5	mA
			TIL603 TIL607 TIL611 TIL615	4		8	mA
			TIL604 TIL608 TIL612 TIL616	7			mA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 0.4\ mA$, $E_e = 20\ mW/cm^2$, See Note 2	ALL		0.15		V

NOTES: 1. Derate linearly to 125°C at the rate of 0.5 mW/°C.
2. Irradiance (E_e) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TYP	UNIT
t_r	Rise Time	$V_{CC} = 30\ V$, $I_L = 800\ \mu A$,	8	μs
t_f	Fall Time	$R_L = 1\ k\Omega$, See Figure 1	6	

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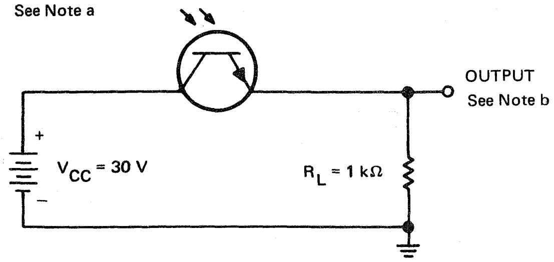
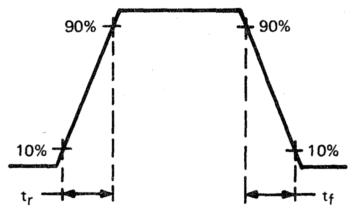
PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



OUTPUT VOLTAGE WAVEFORM

FIGURE 1

NOTES: a. Input irradiance is supplied by a pulsed gallium arsenide infrared emitter with rise and fall times of less than 50 ns. Incident irradiation is adjusted for I_L = 800 μA.

b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 25$ ns, $R_{in} \geqslant 1$ MΩ, $C_{in} \leqslant 20$ pF.

TYPICAL APPLICATION DATA

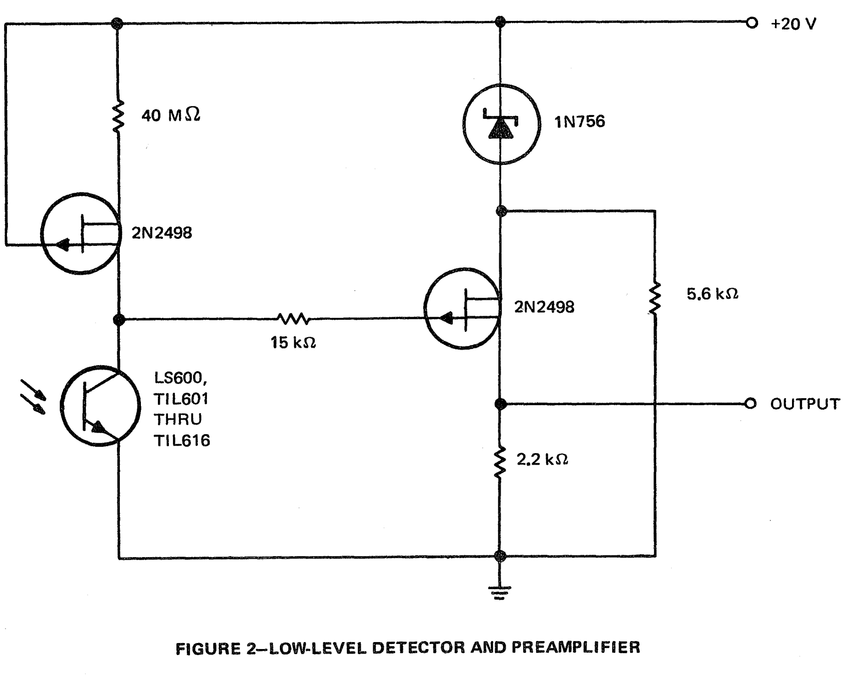


FIGURE 2–LOW-LEVEL DETECTOR AND PREAMPLIFIER

TYPICAL APPLICATION DATA

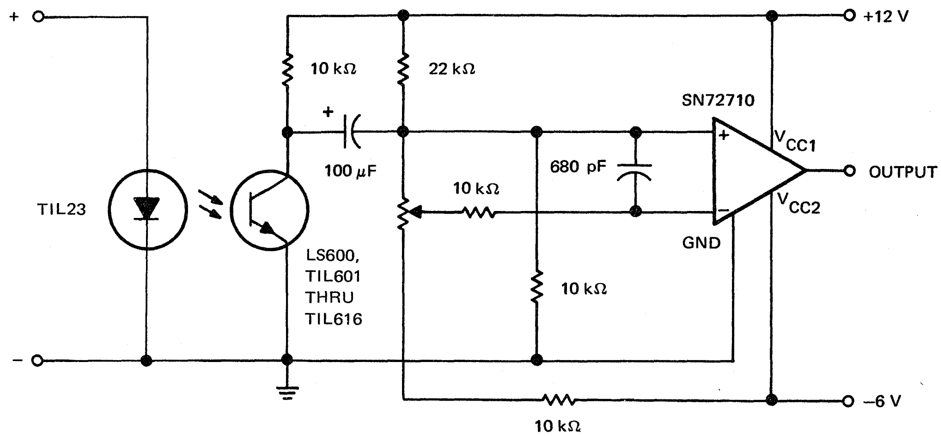


FIGURE 3—OPTICALLY COUPLED AMPLIFIER

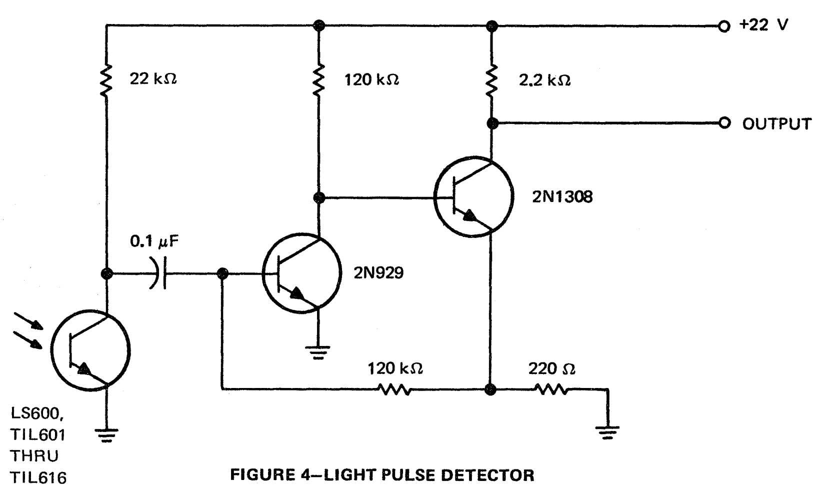


FIGURE 4—LIGHT PULSE DETECTOR

TYPICAL CHARACTERISTICS

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

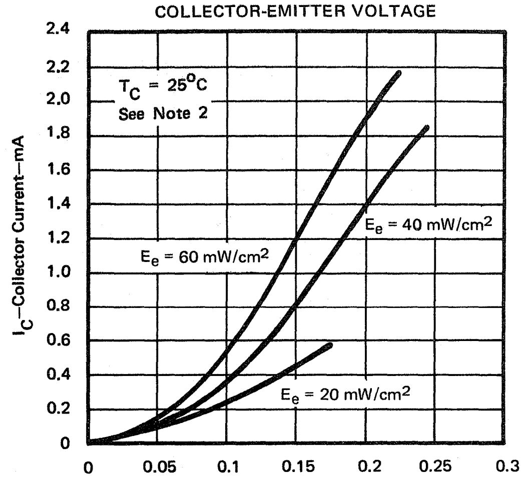


FIGURE 5

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

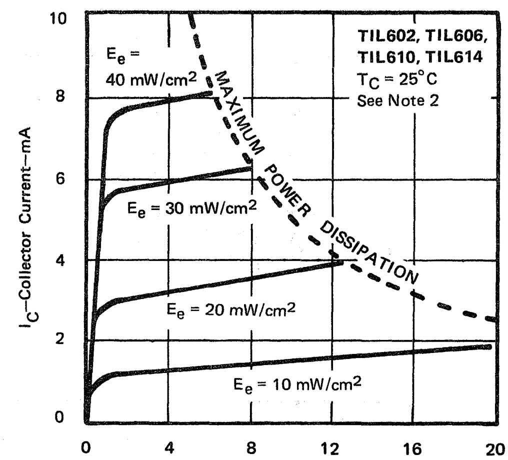


FIGURE 6

COLLECTOR-EMITTER SATURATION VOLTAGE
vs
IRRADIANCE

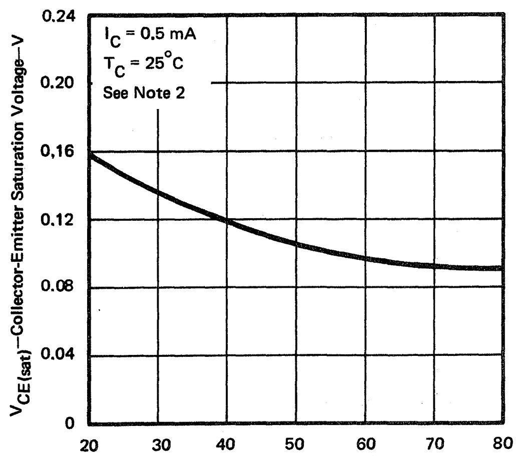


FIGURE 7

COLLECTOR CURRENT
vs
IRRADIANCE

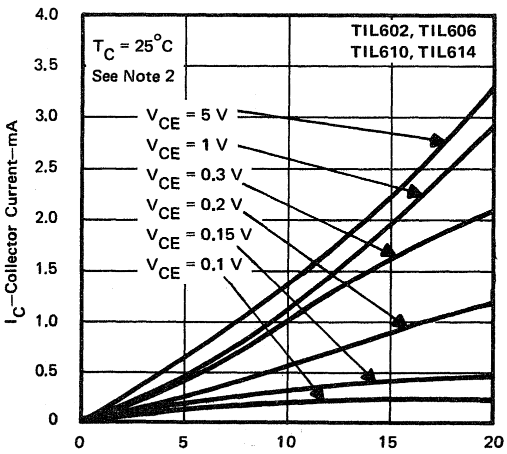


FIGURE 8

NOTE 2: Irradiance (E_e) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

TYPICAL CHARACTERISTICS

DARK CURRENT
vs
CASE TEMPERATURE

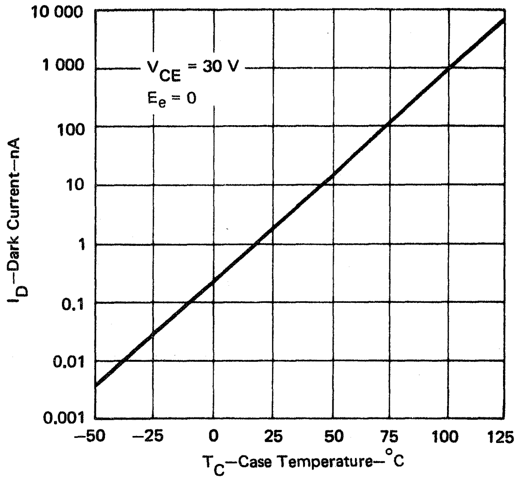


FIGURE 9

RELATIVE OUTPUT
vs
MODULATION FREQUENCY

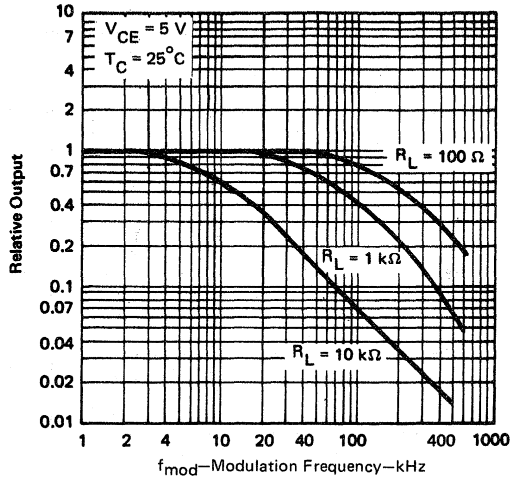


FIGURE 10

COUPLING CHARACTERISTICS
OF TIL23 OR TIL24 WITH
TIL602, TIL606, TIL610, OR TIL614

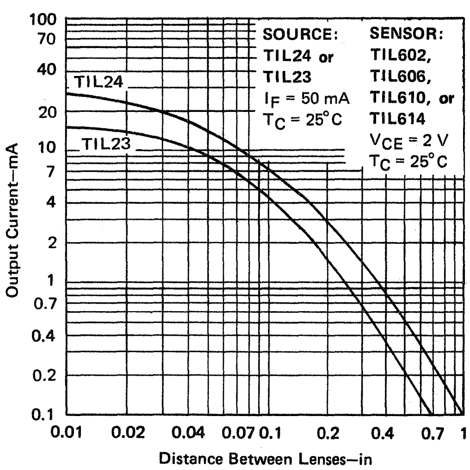


FIGURE 11

RELATIVE OUTPUT
vs
CASE TEMPERATURE OF SOURCE AND SENSOR

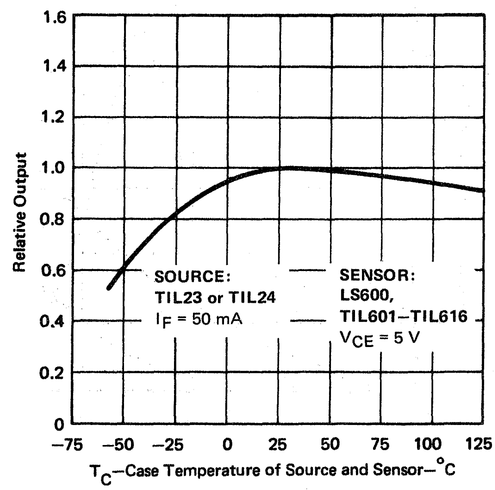


FIGURE 12

TYPICAL CHARACTERISTICS

NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

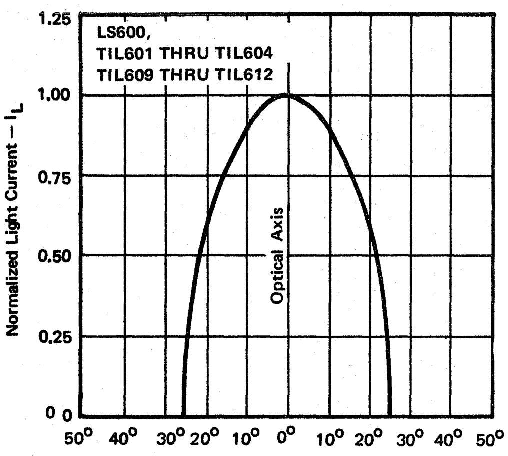


FIGURE 13

NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

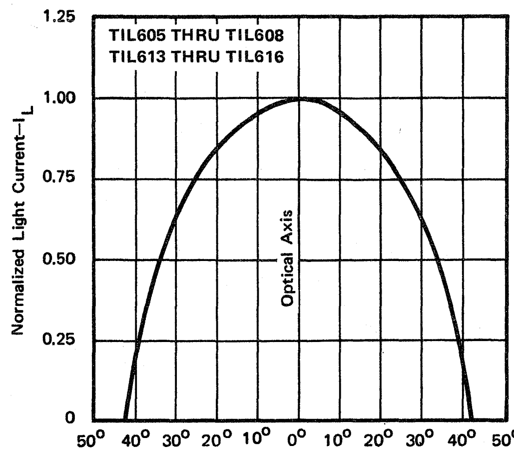


FIGURE 14

RELATIVE SPECTRAL CHARACTERISTICS

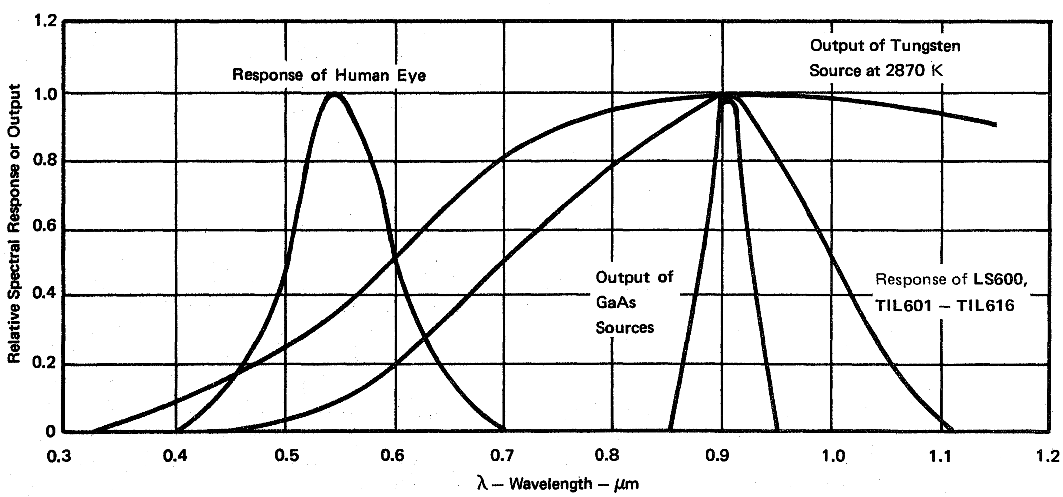


FIGURE 15

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4

TEXAS INSTRUMENTS CUSTOMIZED OPTOELECTRONIC ARRAYS

The LS600, TIL601 through TIL616 series is available mounted in printed circuit boards for custom-designed array or matrix applications. The array is a complete unit, without the problems associated with small, difficult-to-handle components. These arrays can be designed for punched-card or tape readers, position indicators, pattern and character recognition, shaft encoders, and many other special applications.

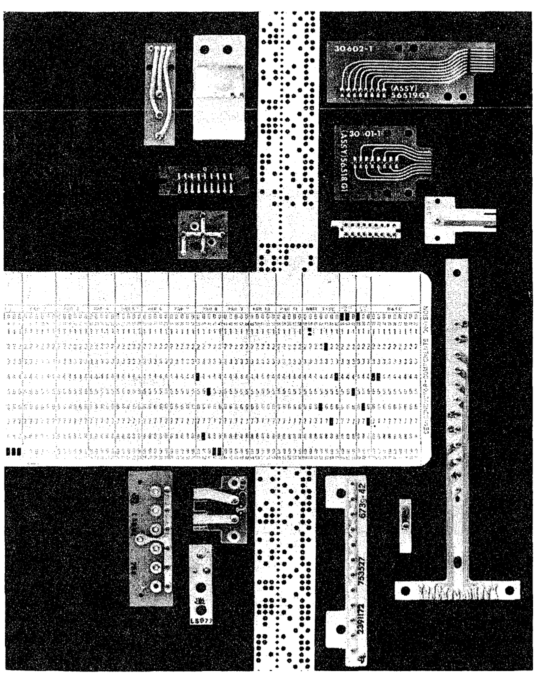
Texas Instruments custom-array techniques offer many advantages:

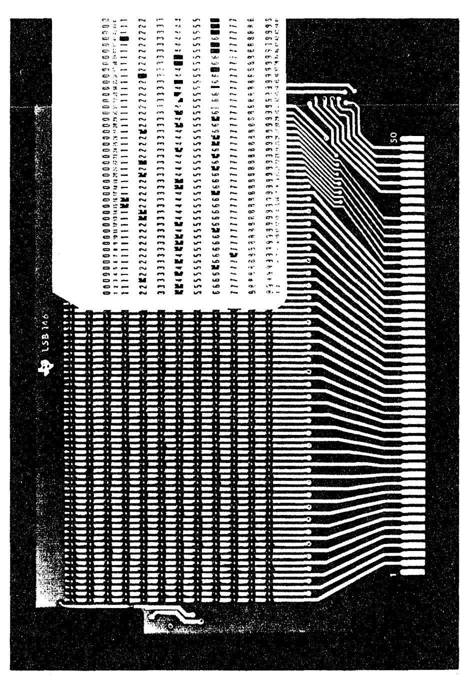
- The arrays are pre-assembled and tested, ready for installation.
- Custom arrays can be manufactured in almost any configuration to allow maximum design flexibility.
- Sensitivity across an entire array will be matched to within 50%.
- Associated components such as ICs and switches can be mounted directly on the printed circuit board.
- Arrays with components firmly soldered into place on both sides of a printed circuit board are more rugged than individually wired sensing devices.

Specifying optoelectronic arrays is easy; all that is required is a print of the array and the desired specifications.

TI sales engineers will assist in developing specifications for special applications.

Standard card-reader and tape-reader arrays are available.





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PRINTED IN U.S.A. 1174

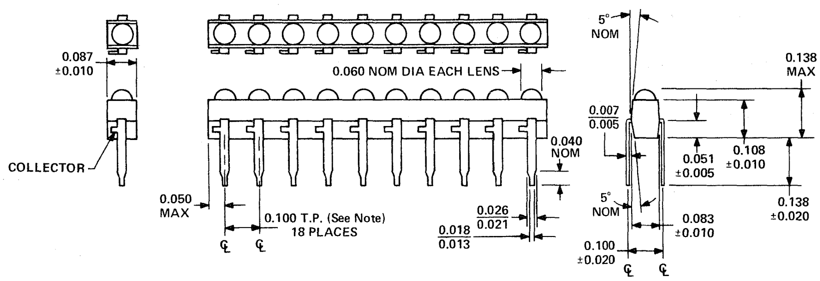
BULLETIN NO. DL-S 7612229, NOVEMBER 1974—REVISED MARCH 1976

- **Spectrally and Mechanically Matched to TIL41 thru TIL50 IR-Emitter Arrays**
- **Recommended for Application in Tape and Card Readers and Encoders**
- **Single Element or Arrays from 2 to 10 Elements**
- **Center-to-Center Spacing of 0.100 Inch**

TYPE NUMBER	TIL621	TIL622	TIL623	TIL624	TIL625	TIL626	TIL627	TIL628	TIL629	TIL630
NUMBER OF ELEMENTS	1	2	3	4	5	6	7	8	9	10

mechanical data

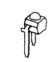
Each device has a clear molded epoxy body with silver-plated leads.



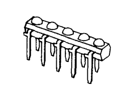
TIL621
SINGLE
ELEMENT
TOP AND
SIDE VIEWS

TIL630
10-ELEMENT ARRAY
TOP AND SIDE VIEWS

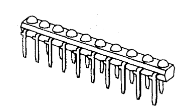
TIL621—TIL630
END VIEW



TIL621



TIL625



TIL630

NOTE: Each pin centerline is located within 0.010 of its true longitudinal position.

All dimensions are in inches unless otherwise noted.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Emitter Voltage	50 V
Emitter-Collector Voltage	7 V
Continuous Device Dissipation of Each Element at (or below) 25°C Free-Air Temperature (See Note 1)	50 mW
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 100°C
Lead Temperature 1/16 Inch below Seating Plane for 3 Seconds	240°C

NOTE 1: Derate linearly to 80°C free-air temperature at the rate of 0.91 mW/°C.

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operating characteristics at 25°C free-air temperature (unless otherwise noted)

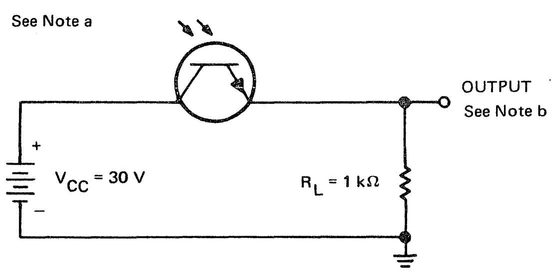
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 100 μA, E_e = 0	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	I_E = 100 μA, E_e = 0	7			V
I_D	Dark Current	V_{CE} = 30 V, E_e = 0			50	nA
		V_{CE} = 30 V, E_e = 0, T_A = 80°C			1	μA
I_L	Light Current	V_{CE} = 5 V, E_e = 5 mW/cm², See Note 2	0.8			mA
$\frac{I_L \text{ max}}{I_L \text{ min}}$	Light Current Matching Factor	V_{CE} = 5 V, E_e = 5mW/cm²	0.5			
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 0.4 mA, E_e = 5 mW/cm²		0.25		V

NOTE 2: Irradiance (E_e) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

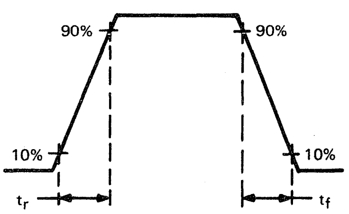
switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_r	Rise Time	V_{CC} = 30 V, I_L = 800 μA,		8		μs
t_f	Fall Time	R_L = 1 kΩ, See Figure 1		6		μs

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



OUTPUT VOLTAGE WAVEFORM

FIGURE 1

NOTES: a. Input irradiance is supplied by a pulsed gallium arsenide infrared emitter with rise and fall times less than 50 ns. Incident irradiation is adjusted for I_L = 800 μA.

b. Output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 25$ ns, $R_{in} \geqslant 1$ MΩ, $C_{in} \leqslant 20$ pF.

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LS600 RELIABILITY DATA

INTRODUCTION

Texas Instruments designs and builds quality and reliability into all the products which it offers in the electronic marketplace. The quality control organization is uniquely responsible for coordinating the total effort and for providing direct action necessary to assure that quality and reliability objectives are met. Accordingly, quality control reaches from raw material inputs to evaluation of finished goods as evidenced by the many inspections and tests shown on the typical light sensor flow diagram in Figure 1.

The reliability data shown in this report are based on extensive tests performed by Texas Instruments to assure continued leadership in optical sensor quality and reliability. More than 24,000 units have been subjected to life test with an accumulation of over 23,000,000 device hours. The data are complete representing all devices produced during the years 1966 through 1974. The tests were performed on ungraded, unburned-in devices and are typical of TI sensor products.

OPERATING LIFE TESTS

The 25°C life tests were performed with incident light intensity adjusted for power dissipation of each device of 50 milliwatts at 10 volts V_{CE}. Readings of dark current (I_D) and light current (I_L) were made at 0, 250, 500, and 1000 hours. Failure criteria were 0.2 μA maximum for I_D and 20% degradation of limits for I_L. A total of 3210 sensors were tested to these criteria with 6 failures. These samples were taken from lots whose total count exceeded 1,050,000 sensors. Data from these tests are shown in Figure 2.

The 55°C life tests were performed with incident light intensity adjusted for power dissipation on each device of 50 milliwatts at V_{CE} = 10 V. Readings of dark current (I_D) and light current (I_L) were made at 0, 168, and 1000 hours. Failure criteria were 0.2 μA maximum for I_D and ±40% change in I_L within original specification limits. A total of 9709 units were tested to these criteria with 41 failures. These samples were taken from lots whose total count exceeded 4,420,000 sensors. Data from these tests are shown in Figure 3.

The long-term reliability of the LS600 sensor is demonstrated by the plots shown in Figure 6 and Figure 7. The data is completely representative of all tests conducted during the reporting period. The projected degradation limits are based upon the exponential distribution of failure. Extended tests performed on small samples confirm that the degradation is within the limits as shown.

ENVIRONMENTAL TESTS

The tests listed in Figure 8 were performed on samples of the product with no catastrophic or degradation failures observed. It must be pointed out that test conditions shown are not the ultimate strength of the product but represent the test requirements imposed by our customers. The ultimate strength of these devices is much higher in most cases. Inquiries concerning response to particular requirements should be addressed to your TI sales representative.

HIGH-TEMPERATURE REVERSE BIAS

Devices are stored in dark ovens at 150°C with 45 volts applied for 1000 hours. Readings of dark current (I_D), breakdown voltage ($V_{(BR)CEO}$), and light current (I_L) were made at 0, 168, and 1000 hours. Failure criteria were 0.2 μA maximum for I_D and 60% degradation within original limits for I_L. A total of 9673 units were tested to these criteria with 56 failures. These samples were taken from lots whose total count exceeded 4,400,000 sensors. Data from these tests are shown in Figure 4.

STORAGE LIFE TESTS

Devices were stored in ovens at 150°C for 500 and 1000 hours (depending upon requirements). Readings of dark current (I_D) and light current (I_L) were made at 0, 250, and 1000 hours. Failure criteria were 0.2 μA maximum for I_D and 20% degradation of limits for I_L. A total of 1829 units were tested to these criteria with 6 failures. These samples were taken from lots whose total count exceeded 745,000 sensors. Data from these tests are shown in Figure 5.

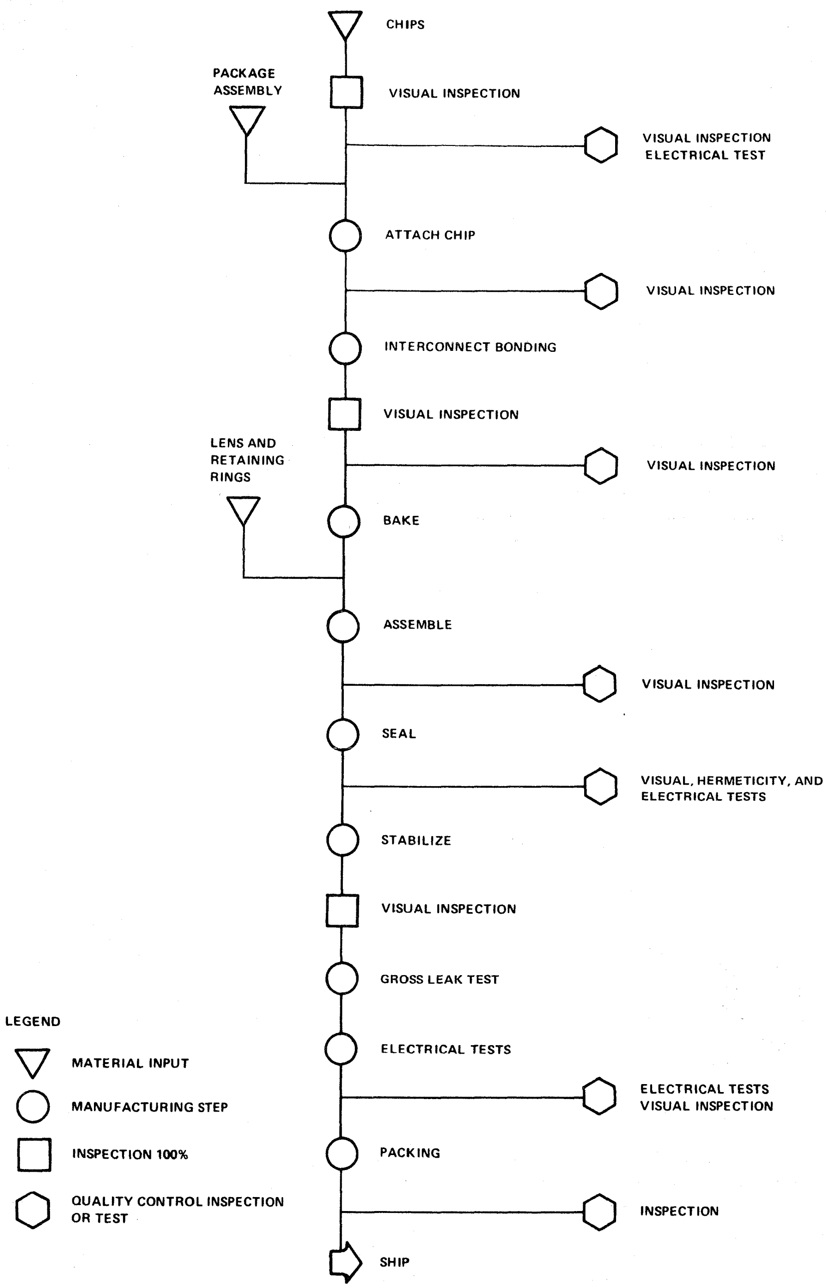
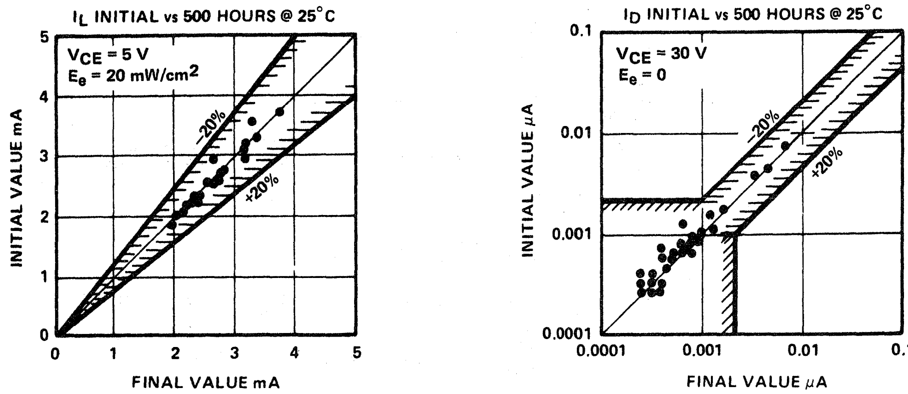
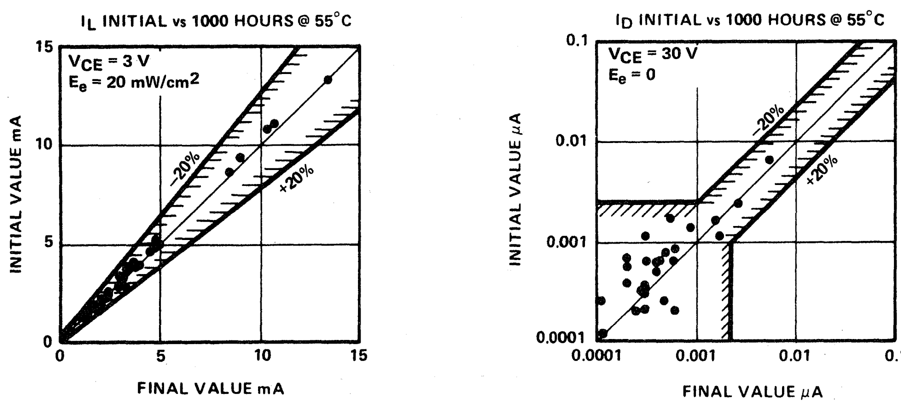


FIGURE 1. Typical Light Sensor Flow Diagram



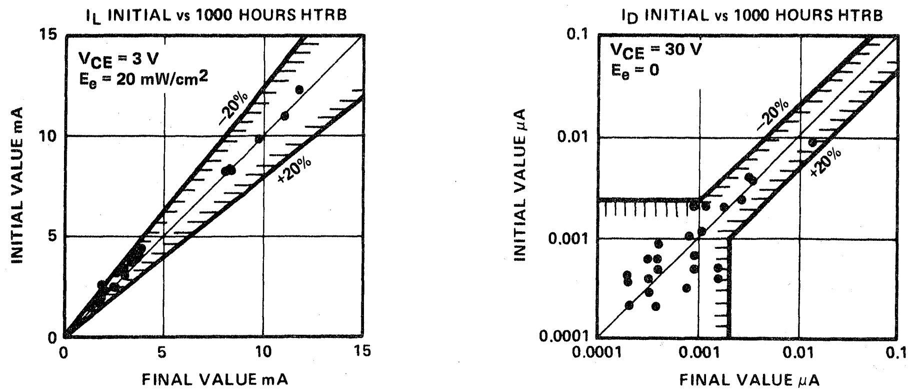
UNITS TESTED	UNIT HOURS	CATASTROPHIC FAILURES	DEGRADATION FAILURES			
			TOTAL	FAILURE RATE IN %/1,000 HOURS		MEAN TIME BETWEEN FAILURES
				60% CONFIDENCE	90%CONFIDENCE	
3210	2,847,000	0	6	0.20	0.33	700,00 HOURS

FIGURE 2. Operating Life at 25°C



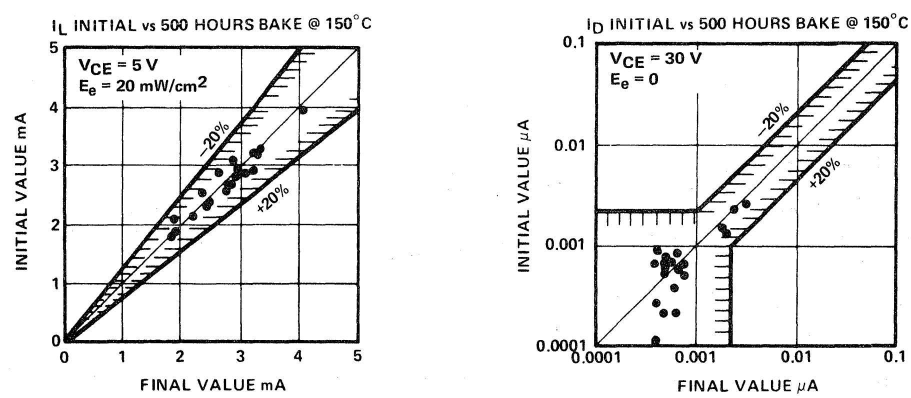
UNITS TESTED	UNIT HOURS	CATASTROPHIC FAILURES	DEGRADATION FAILURES			
			TOTAL	FAILURE RATE IN%/1,000 HOURS		MEAN TIME BETWEEN FAILURES
				60% CONFIDENCE	90%CONFIDENCE	
9709	9,709,00	0	41	0.44	0.51	236,800 HOURS

FIGURE 3. Operating Life at 55°C.



UNITS TESTED	UNIT HOURS	CATASTROPHIC FAILURES	DEGRADATION FAILURES			
			TOTAL	FAILURE RATE IN %/1,000 HOURS		MEAN TIME BETWEEN FAILURES
				60% CONFIDENCE	90%CONFIDENCE	
9,673	9,673,000	0	0.56	0.60	0.68	172,700 HOURS

FIGURE 4. High-Temperature Reverse Bias



UNITS TESTED	UNIT HOURS	CATASTROPHIC FAILURES	DEGRADATION FAILURES			
			TOTAL	FAILURE RATE IN%/1,000 HOURS		MEAN TIME BETWEEN FAILURES
				60% CONFIDENCE	90%CONFIDENCE	
1829	963,500	0	0	0.78	1.1	160,000 HOURS

FIGURE 5. High-Temperature Storage

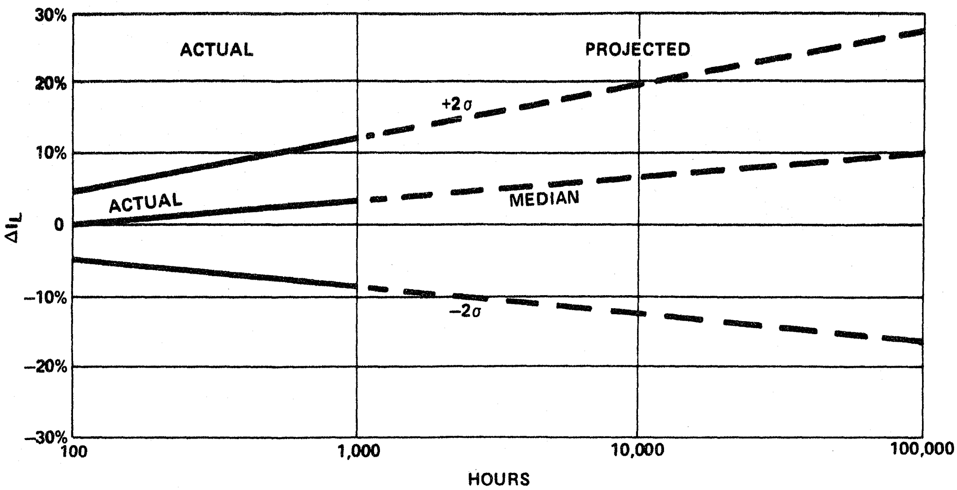


FIGURE 6. % ΔI_L vs Operating Life at 25°C

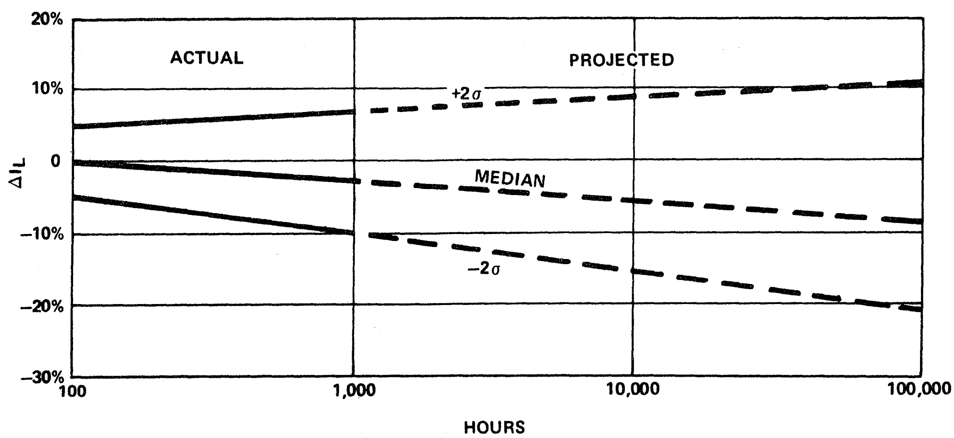


FIGURE 7. % ΔI_L vs Operating Life at 55°C

4

MIL-STD-750 Test Method	Test	Quantity Tested	Failures (Catastrophic or Degradation)
2026	Solderability: 240°C, 3 Minutes	126	0
1051	Temperature Cycle: 5 Cycles, 30 Min., −65 to +125°C	126	0
1051	Temperature Cycle −40°C to 100°C, 5 Cycles, 30 Minutes	8800	3
1056	Thermal Shock: 5 Cycles	126	0
1021	Moisture Resistance	126	0
2016	Shock, Impact: 1000 g, 5 Each Axis, 0.5 millisecond	126	0
2056	Vibration, Variable Frequency: 10g	8926	9
2046	Vibration Fatigue: 10g	126	0
2006	Constant Acceleration: 10kg, 1 Min.	126	0
1001	Barometric Pressure: 15mmHg, 45 V	126	0
1071	Hermetic Seal: Test Condition E	8800	0

FIGURE 8. Environmental Test Results

TIL601HR THROUGH TIL604HR HIGH-RELIABILITY PHOTOTRANSISTORS

Texas Instruments has always been known as a producer of high-quality products, and the LS600 series phototransistor is no exception as evidenced by the testing of more than 24,000 units with an accumulation of over 23,000,000 hours without a catastrophic failure. This small pill-package transistor, developed by Texas Instruments, has amassed a 10-year record of reliability in both military and aero-space applications. Utilizing the expertise, techniques, and processes developed during these years of building the LS600 phototransistors to high-reliability customer specifications, Texas Instruments now offers the TIL601HR thru TIL604HR as standard high-reliability devices to customers requiring extra reliability in their applications.

The phototransistors and the complementary TIL23HR and TIL24HR infrared emitters are now available as standard product items. For more information, contact your nearest TI sales representative, or Optoelectronics Department Product Marketing.

5

Opto-couplers

OPTO-COUPLERS
QUICK REFERENCE GUIDE

DEVICE	ISOLATION VOLTAGE	$I_{C(on)}$			$I_{C(off)}$			$V_{CE(sat)}$		V_F		FEATURES
		MIN mA	TYP mA	@ I_F mA	TYP nA	MAX nA	@ V	MAX V	@ I_F mA	MAX V	@ I_F mA	
4N22	±1 kV	2.5	4	10		100	20	0.3	20	1.3	10	Base lead provided for conventional transistor biasing. Hermetically sealed package. JEDEC registered.
4N23	±1 kV	6	8	10		100	20	0.3	20	1.3	10	
4N24	±1 kV	10	15	10		100	20	0.3	20	1.3	10	
TIL102	±1 kV	2.5	6	10	6	100	20	0.3	20	1.3	10	Base lead provided for conventional transistor biasing. Hermetically sealed package.
			0.04†	10	0.1†		20					
TIL103	±1 kV	10	15	10	6	100	20	0.3	20	1.3	10	
			0.04†	10	0.1†		20					
TIL107	±1 kV	0.5	1	15		25	30	0.3	15	1.5	15	Hermetically sealed package.
		1.6	4	35								
TIL108	±1 kV	1.6	2	15		25	30	0.3	15	1.5	15	
		5	7	35								
TIL109	±5 kV	0.25	1.5	35		500	5	0.3	15	1.9	35	Precast epoxy package
TIL111	±1.5 kV	2	7	16	1	50	10	0.4	16	1.4	16	Base lead provided for conventional transistor biasing. Six-pin dual-in-line plastic package.
		0.01†	0.02†	16	0.1†	20†	10					
TIL112	±1.5 kV	0.2	2	10	1	100	5	0.5	50	1.5	10	
		0.002†	0.01†	10	0.1†	50†	5					
TIL113	±1.5 kV	30	100	10		100	10	1	50	1.5	10	
TIL114	±2.5 kV	2	7	16	1	50	10	0.4	16	1.4	16	
		0.01†	0.02†	16	0.1†	20†	10					
TIL115	±1.5 kV	0.2	2	10	1	100	5	0.5	50	1.5	10	
		0.002†	0.01†	10	0.1†	50†	5					
TIL116	±2.5 kV	2	5	10	1	50	10	0.4	15	1.5	60	
		0.01†	0.02†	16	0.1†	20†	10					
TIL117	±2.5 kV	5	9	10	1	50	10	0.4	10	1.4	16	
		0.01†	0.02†	16	0.1†	20†	10†					
TIL118	±1.5 kV	1	2	10	1	100	5	0.5	50	1.5	10	Six-pin dual-in-line plastic package
TIL119	±1.5 kV	30	160	10		100	10	1	10	1.5	10	
TIL120	±1 kV	2.5	6	10	6	100	20	0.3	20	1.3	10	Hermetically sealed TO-72 package
TIL121	±1 kV	5	10	10	6	100	20	0.3	20	1.3	10	

†Photodiode operation

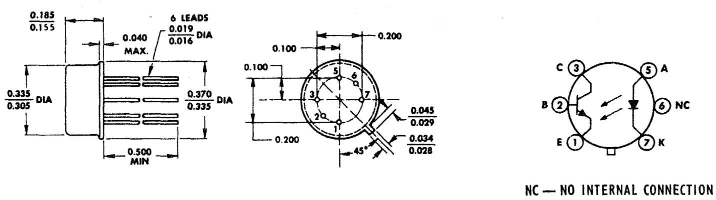
BULLETIN NO. DL-S 7312013, AUGUST 1973

JEDEC REGISTERED DEVICES
GALLIUM ARSENIDE DIODE INFRARED SOURCE OPTICALLY COUPLED TO A HIGH-GAIN N-P-N SILICON PHOTOTRANSISTOR

- Photon Coupling for Isolator Applications
- Base Lead Provided for Conventional Transistor Biasing
- High Overall Current Gain . . . 1.5 Typ (4N24)
- High-Gain, High-Voltage Transistor . . . h_{FE} = 800 Typ (4N24), $V_{(BR)CEO}$ = 35 V Min
- High-Voltage Electrical Isolation . . . 1-kV Rating
- Stable over Wide Temperature Range

*mechanical data

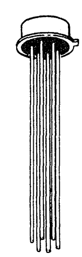
THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE



NC — NO INTERNAL CONNECTION

Dimensions without tolerance designate true position. Leads having maximum diameter (0.019") measured in gaging plane 0.054" +0.001" −0.000" below the seating plane of the device shall be within 0.007" of their true positions relative to a maximum-width tab.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



5

*absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Input-to-Output Voltage	±1 kV
Collector-Base Voltage	35 V
Collector-Emitter Voltage (See Note 1)	35 V
Emitter-Base Voltage	4 V
Input Diode Reverse Voltage	2 V
Input Diode Continuous Forward Current at (or below) 65°C Free-Air Temperature (See Note 2)	40 mA
Continuous Collector Current	50 mA
Peak Diode Current (See Note 3)	1A
Continuous Transistor Power Dissipation at (or below) 25°C Free-Air Temperature (See Note 4)	300 mW
Storage Temperature Range	−55°C to 125°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

NOTES: 1. This value applies with the emitter-base diode open-circuited and the input-diode current equal to zero.
2. Derate linearly to 125°C free-air temperature at the rate of 0.67 mA/°C.
3. This value applies for $t_w \leqslant 1\ \mu s$, PRR $\leqslant$ 300 pps.
4. Derate linearly to 125°C free-air temperature at the rate of 3 mW/°C.

*JEDEC registered data. This data sheet contains all applicable JEDEC registered data in effect at the time of publication.

*electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	4N22			4N23			4N24			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 100\ \mu A$, $I_E = 0$, $I_F = 0$	35			35			35			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 1\ mA$, $I_B = 0$, $I_F = 0$	35			35			35			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 100\ \mu A$, $I_C = 0$, $I_F = 0$	4			4			4			V
I_R	Input Diode Static Reverse Current	$V_R = 2\ V$			100			100			100	μA
$I_{C(on)}$	On-State Collector Current	$V_{CE} = 5\ V$, $I_B = 0$, $I_F = 2\ mA$	0.15			0.2			0.4			mA
		$V_{CE} = 5\ V$, $I_B = 0$, $I_F = 10\ mA$, $T_A = -55°C$	1			2.5			4			
		$V_{CE} = 5\ V$, $I_B = 0$, $I_F = 10\ mA$	2.5	4		6	8		10	15		
		$V_{CE} = 5\ V$, $I_B = 0$, $I_F = 10\ mA$, $T_A = 100°C$	1			2.5			4			
$I_{C(off)}$	Off-State Collector Current	$V_{CE} = 20\ V$, $I_B = 0$, $I_F = 0$			100			100			100	nA
		$V_{CE} = 20\ V$, $I_B = 0$, $I_F = 0$, $T_A = 100°C$			100			100			100	μA
V_F	Input Diode Static Forward Voltage	$I_F = 10\ mA$, $T_A = -55°C$	1		1.5	1		1.5	1		1.5	V
		$I_F = 10\ mA$	0.8		1.3	0.8		1.3	0.8		1.3	
		$I_F = 10\ mA$, $T_A = 100°C$	0.7		1.2	0.7		1.2	0.7		1.2	
$V_{CE(sat)}$	Collector-Emitter Stauration Voltage	$I_C = 2.5\ mA$, $I_B = 0$, $I_F = 20\ mA$			0.3							V
		$I_C = 5\ mA$, $I_B = 0$, $I_F = 20\ mA$						0.3				
		$I_C = 10\ mA$, $I_B = 0$, $I_F = 20\ mA$									0.3	
r_{IO}	Input-to-Output Internal Resistance	$V_{in\text{-}out} = \pm 1\ kV$, See Note 5	10^{11}			10^{11}			10^{11}			Ω
C_{io}	Input-to-Output Capacitance	$V_{in\text{-}out} = 0$, $f = 1\ MHz$, See Note 5			5			5			5	pF

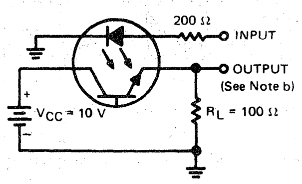
*switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	4N22			4N23			4N24			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
t_r	Rise Time	$V_{CC} = 10\ V$, $I_{F(on)} = 10\ mA$,			15			15			20	μs
t_f	Fall Time	$R_L = 100\ \Omega$, See Figure 1			15			15			20	μs

NOTE 5: These parameters are measured between all the input diode leads shorted together and all the phototransistor leads shorted together.

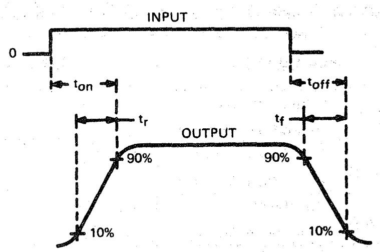
*JEDEC registered data

*PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

Adjust amplitude of input pulse for $I_{F(on)}$ = 10 mA



VOLTAGE WAVEFORMS

NOTES: a. The input waveform is supplied by a generator with the following characteristics: Z_{out} = 50 Ω, $t_r \leq 15$ ns, t_w = 100 μs, duty cycle ≈ 1%.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 12$ ns, $R_{in} \geq$ MΩ, $C_{in} \leq 20$ pF.

*JEDEC registered data

FIGURE 1—SWITCHING TIMES

TYPICAL CHARACTERISTICS

4N22

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

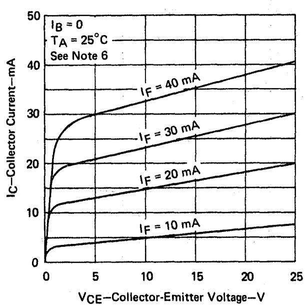


FIGURE 2

4N23

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

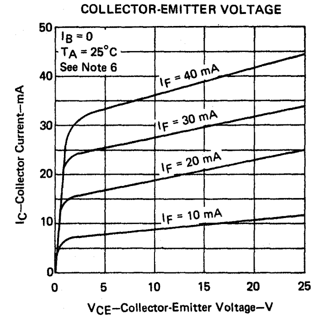


FIGURE 3

4N24

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

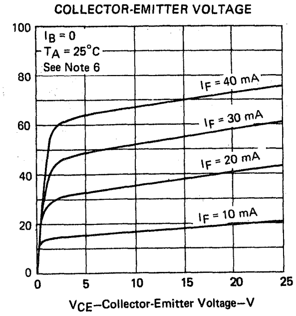


FIGURE 4

NOTE 6: This parameter was measured using pulse techniques. t_w = 100 μs, duty cycle = 1%.

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TYPICAL CHARACTERISTICS

INPUT DIODE FORWARD CONDUCTION CHARACTERISTICS

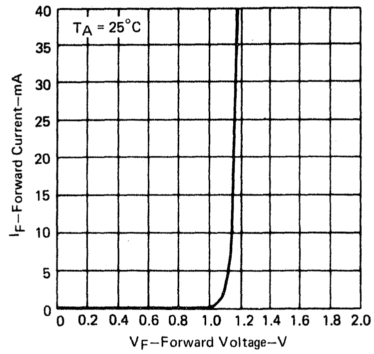
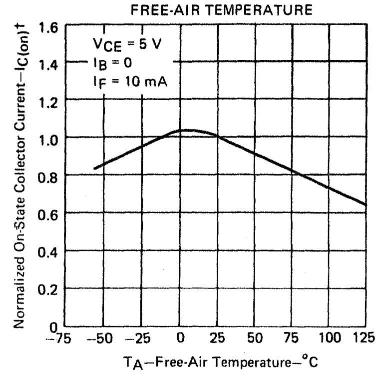


FIGURE 5

NORMALIZED ON-STATE COLLECTOR CURRENT†
vs
FREE-AIR TEMPERATURE



†Normalized to value at T_A = 25°C

FIGURE 6

PHOTOTRANSISTOR COLLECTOR CURRENT
vs
INPUT-DIODE FORWARD CURRENT

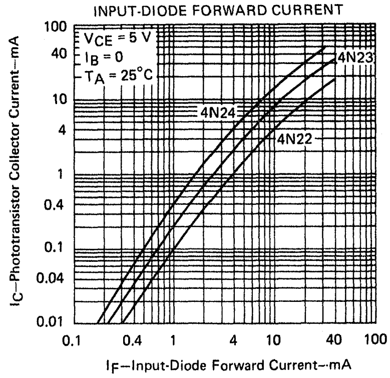


FIGURE 7

OFF-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

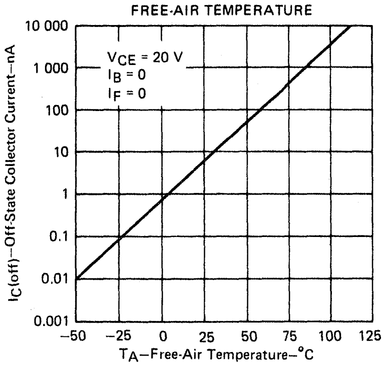


FIGURE 8

4N22, 4N23
AVERAGE SWITCHING TIME
vs
LOAD RESISTANCE

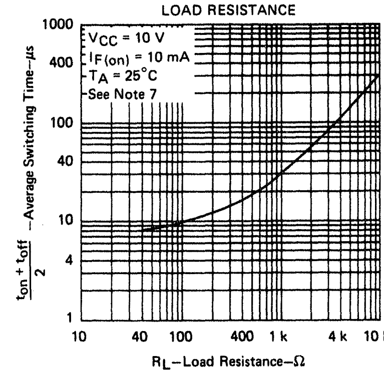


FIGURE 9

NOTE 7: This parameter was measured in the test circuit of Figure 1 with R_L varied between 40 Ω and 10 kΩ.

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PRINTED IN U.S.A. 873

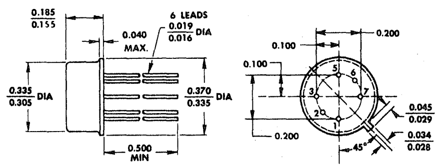
BULLETIN NO. DL-S 7011388, SEPTEMBER 1970

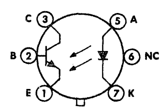
GALLIUM ARSENIDE DIODE INFRARED SOURCE OPTICALLY COUPLED TO A HIGH-GAIN N-P-N SILICON PHOTOTRANSISTOR

- Photon Coupling for Isolator Applications
- Base Lead Provided for Conventional Transistor Biasing
- High Overall Current Gain . . . 1.5 Typ (TIL103)
- High-Gain, High-Voltage Transistor . . . h_{FE} = 500 Typ (TIL103), $V_{(BR)CEO}$ = 35 V Min
- High-Voltage Electrical Isolation . . . 1-kV Rating
- Stable over Wide Temperature Range

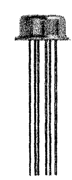
mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





NC — NO INTERNAL CONNECTION



Dimensions without tolerance designate true position. Leads having maximum diameter (0.019") measured in gaging plane 0.054" +0.001" −0.000" below the seating plane of the device shall be within 0.007" of their true positions relative to a maximum-width tab.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Input-to-Output Voltage	±1 kV
Collector-Emitter Voltage	35 V
Collector-Base Voltage	35 V
Emitter-Base Voltage	4 V
Input Diode Reverse Voltage	2 V
Input Diode Continuous Forward Current at (or below) 65°C Free-Air Temperature (See Note 1)	40 mA
Continuous Collector Current	50 mA
Continuous Transistor Power Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	300 mW
Storage Temperature Range	−55°C to 125°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

NOTES: 1. Derate linearly to 125°C free-air temperature at the rate of 0.67 mA/°C.
2. Derate linearly to 125°C free-air temperature at the rate of 3 mW/°C.

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER			TEST CONDITIONS	TIL102 MIN	TIL102 TYP	TIL102 MAX	TIL103 MIN	TIL103 TYP	TIL103 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage		$I_C = 100\ \mu A$, $I_E = 0$, $I_F = 0$	35			35			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage		$I_C = 1$ mA, $I_B = 0$, $I_F = 0$	35			35			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage		$I_E = 100\ \mu A$, $I_C = 0$, $I_F = 0$	4			4			V
I_R	Input Diode Static Reverse Current		$V_R = 2$ V			100			100	μA
$I_{C(on)}$	On-State Collector Current	Phototransistor Operation	$V_{CE} = 5$ V, $I_B = 0$, $I_F = 10$ mA	2.5	6		10	15		mA
		Photodiode Operation	$V_{CB} = 5$ V, $I_E = 0$, $I_F = 10$ mA		40			40		μA
$I_{C(off)}$	Off-State Collector Current	Phototransistor Operation	$V_{CE} = 20$ V, $I_B = 0$, $I_F = 0$		6	100		6	100	nA
			$V_{CE} = 20$ V, $I_B = 0$, $I_F = 0$, $T_A = 100°C$		4			4		μA
		Photodiode Operation	$V_{CB} = 20$ V, $I_E = 0$, $I_F = 0$		0.1			0.1		nA
h_{FE}	Transistor Static Forward Current Transfer Ratio		$V_{CE} = 5$ V, $I_C = 10$ mA, $I_F = 0$		300			500		
V_F	Input Diode Static Forward Voltage		$I_F = 10$ mA			1.3			1.3	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage		$I_C = 2.5$ mA, $I_B = 0$, $I_F = 20$ mA			0.3				V
			$I_C = 10$ mA, $I_B = 0$, $I_F = 20$ mA						0.3	V
r_{IO}	Input-to-Output Internal Resistance		$V_{in\text{-}out} = \pm 1$ kV, See Note 3	10^{11}	10^{12}		10^{11}	10^{12}		Ω
C_{io}	Input-to-Output Capacitance		$V_{in\text{-}out} = 0$, f = 1 MHz, See Note 3		2.5			2.5		pF

NOTE 3: These parameters are measured between both input diode leads shorted together and all the phototransistor leads shorted together.

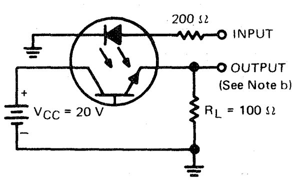
switching characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	TIL102 TYP	TIL103 TYP	UNIT
t_r	Rise Time	Phototransistor Operation	$V_{CC} = 20$ V, $I_B = 0$, $I_{C(on)} = 5$ mA, $R_L = 100\ \Omega$, See Test Circuit A of Figure 1	3	6	μs
t_f	Fall Time			3	6	μs
t_r	Rise Time	Photodiode Operation	$V_{CC} = 20$ V, $I_E = 0$, $I_{C(on)} = 50\ \mu A$, $R_L = 100\ \Omega$, See Test Circuit B of Figure 1	150	150	μs
t_f	Fall Time			150	150	μs

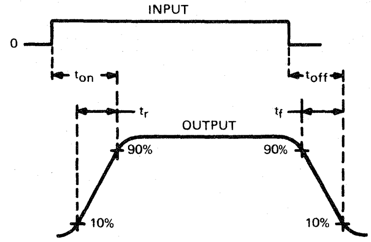
5

PARAMETER MEASUREMENT INFORMATION

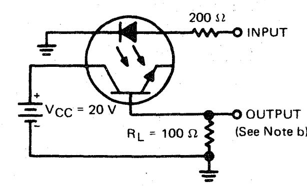
Adjust amplitude of input pulse for:
$I_{C(on)}$ = 5 mA (Test Circuit A) or
$I_{C(on)}$ = 50 μA (Test Circuit B)



TEST CIRCUIT A
PHOTOTRANSISTOR OPERATION



VOLTAGE WAVEFORMS



TEST CIRCUIT B
PHOTODIODE OPERATION

NOTES: a. The input waveform is supplied by a generator with the following characteristics: z_{out} = 50 Ω, $t_r \leqslant$ 15 ns, duty cycle ≈ 1%. For Test Circuit A, t_w = 100 μs. For Test Circuit B, t_w = 1 μs.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant$ 12 ns, $R_{in} \geqslant$ 1MΩ, $C_{in} \leqslant$ 20 pF.

FIGURE 1—SWITCHING TIMES

TYPICAL CHARACTERISTICS

TIL102
COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

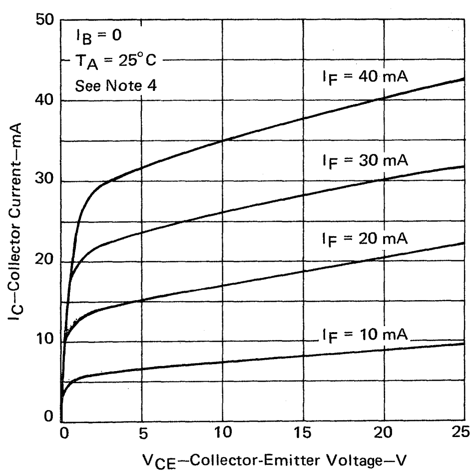


FIGURE 2

TIL103
COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

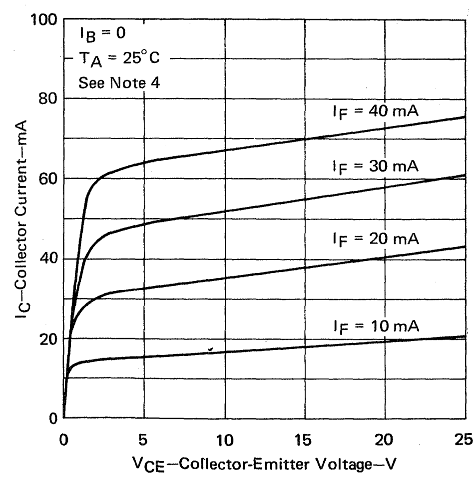


FIGURE 3

NOTE 4: This parameter was measured using pulse techniques. t_w = 100 μs, duty cycle = 1%.

TYPICAL CHARACTERISTICS

INPUT DIODE FORWARD CONDUCTION CHARACTERISTICS

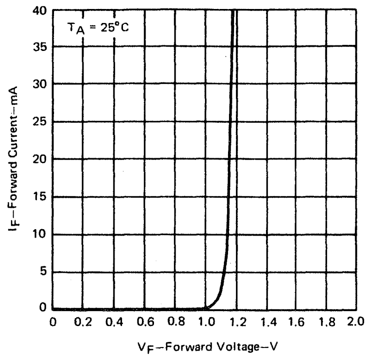
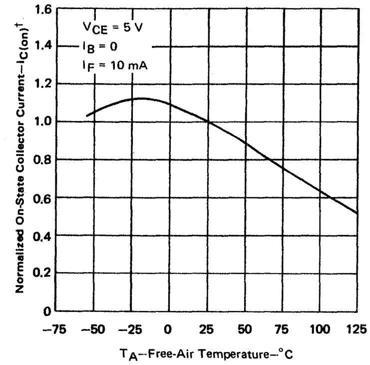


FIGURE 4

NORMALIZED ON-STATE COLLECTOR CURRENT†
vs
FREE-AIR TEMPERATURE



†Normalized to value at T_A = 25°C

FIGURE 5

PHOTOTRANSISTOR COLLECTOR CURRENT
vs
INPUT-DIODE FORWARD CURRENT

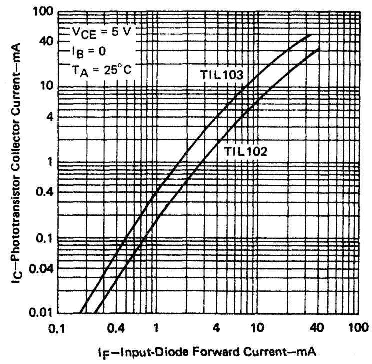


FIGURE 6

OFF-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

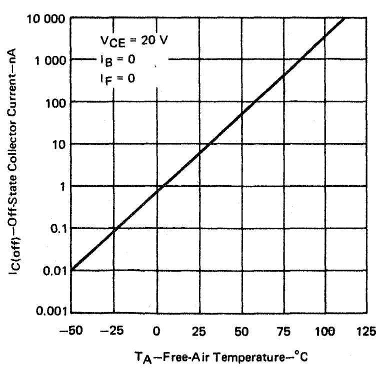


FIGURE 7

TIL102
AVERAGE SWITCHING TIME
vs
LOAD RESISTANCE

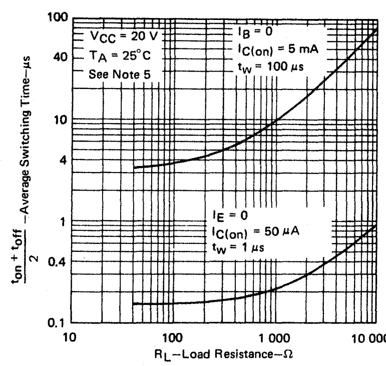


FIGURE 8

NOTE 5: These parameters were measured in Test Circuits A and B of Figure 1 with R_L varied between 40 Ω and 10 kΩ.

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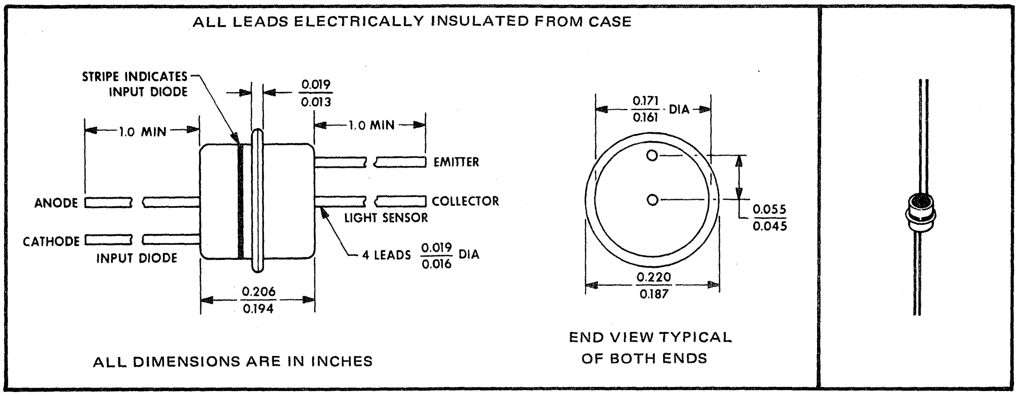
COMPATIBLE WITH STANDARD DTL AND TTL INTEGRATED CIRCUITS

- **Ideal for Replacement of Relays and Pulse Transformers**
- **Gallium Arsenide Diode Infrared Source Optically Coupled to a Silicon N-P-N Phototransistor**
- **High-Voltage Electrical Isolation . . . 1-kV Rating**
- **High Direct-Current Transfer Ratio**
- **High-Speed Switching**
- **Stable over a Wide Temperature Range**
- **Rugged, Hermetically Sealed Package**

5

mechanical data

Welded case with glass-to-metal hermetic seal between case and leads. Unit weight is approximately 4.5 grams.



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Input-to-Output Voltage	± 1 kV
Collector-Emitter Voltage	35 V
Emitter-Collector Voltage	7 V
Input-Diode Reverse Voltage	2 V
Input-Diode Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	50 mA
Continuous Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	150 mW
Storage Temperature Range	−55°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

NOTES: 1. Derate linearly to 125°C free-air temperature at the rate of 0.5 mA/°C.

2. Derate linearly to 125°C free-air temperature at the rate of 1.5 mW/°C. In these devices, a significant portion of the total dissipation is in the input diode. $P_T = V_{CE} I_C + V_F I_F$.

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST FIGURE	TEST CONDITIONS	TIL107 MIN	TIL107 TYP	TIL107 MAX	TIL108 MIN	TIL108 TYP	TIL108 MAX	UNIT
$I_{C(on)}$	On-State Collector Current	A	V_{CE} = 5 V, I_F = 15 mA	0.5	1		1.6	2		mA
			V_{CE} = 5 V, I_F = 35 mA	1.6	4		5	7		
$I_{C(off)}$	Off-State Collector Current	B	V_{CE} = 30 V, I_F = 0			25			25	nA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	C	I_F = 15 mA, I_C = 125 μA			0.3			0.3	V
V_F	Input-Diode Static Forward Voltage	D	I_F = 15 mA			1.5			1.5	V
r_{IO}	Input-to-Output Internal Resistance		$V_{in\text{-}out}$ = ± 1 kV		$>10^{13}$			$>10^{13}$		Ω
C_{io}	Input-to-Output Internal Capacitance		$V_{in\text{-}out}$ = 100 V, f = 50 MHz		0.4			0.4		pF

5

switching characteristics at 25°C free-air temperature

PARAMETER		TEST FIGURE	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_d	Delay Time	E	V_{CC} = 35 V, $I_{C(on)}$ = 500 μA, R_L = 1 kΩ		3.0		μs
t_r	Rise Time				5.0		μs
t_s	Storage Time				0.5		μs
t_f	Fall Time				5.0		μs

TYPICAL CHARACTERISTICS

TIL107

ON-STATE COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

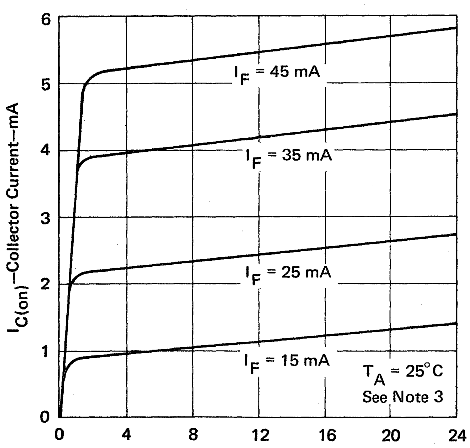


FIGURE 1

TIL108

ON-STATE COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

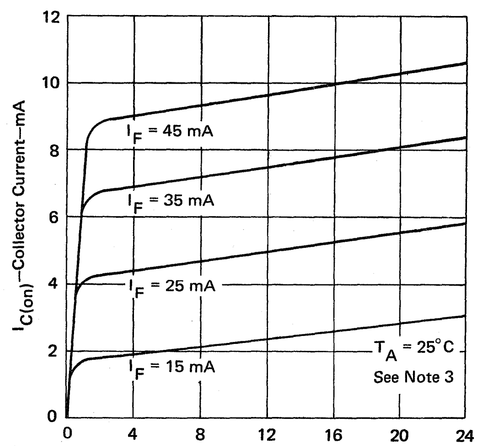


FIGURE 2

NOTE 3: This parameter must be measured using pulse techniques. t_p = 300 μs, duty cycle ⩽ 2%.

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TYPICAL CHARACTERISTICS

PHOTOTRANSISTOR COLLECTOR CURRENT
vs
INPUT-DIODE FORWARD CURRENT

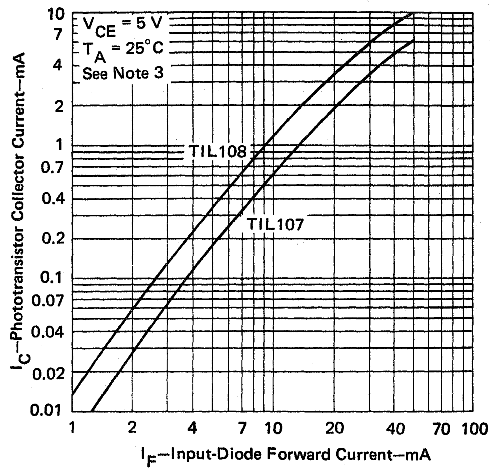


FIGURE 3

OFF-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

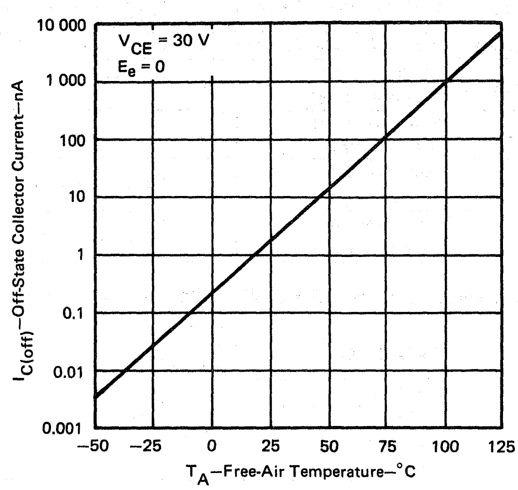


FIGURE 4

RELATIVE OUTPUT
vs
MODULATION FREQUENCY

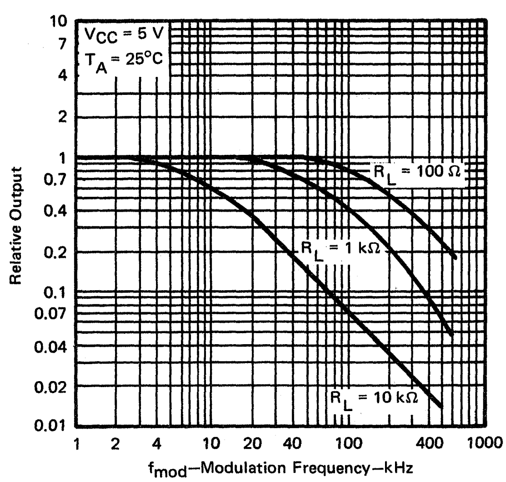


FIGURE 5

RELATIVE OUTPUT
vs
FREE-AIR TEMPERATURE

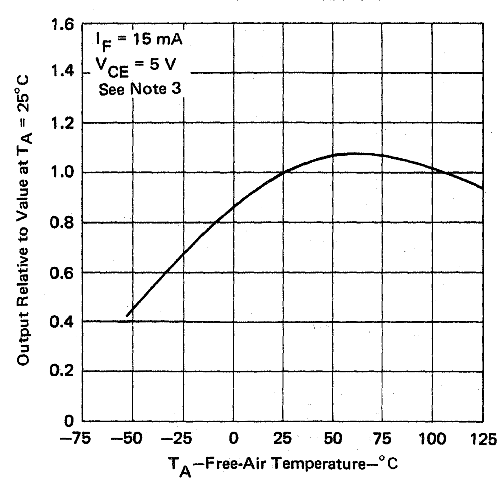


FIGURE 6

NOTE 3: This parameter must be measured using pulse techniques. $t_p = 300\ \mu s$, duty cycle ⩽ 2%.

PARAMETER MEASUREMENT INFORMATION

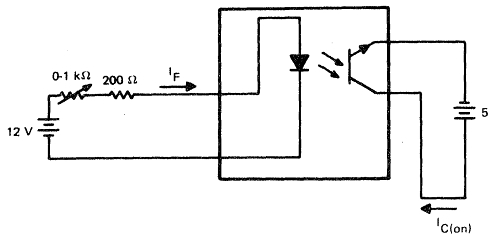


FIGURE A—$I_{C(on)}$

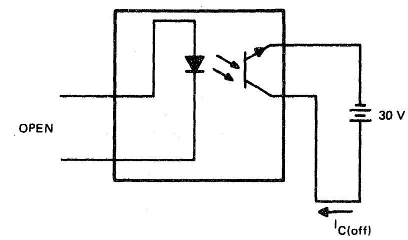


FIGURE B—$I_{C(off)}$

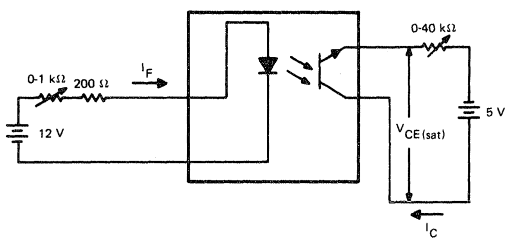


FIGURE C—$V_{CE(sat)}$

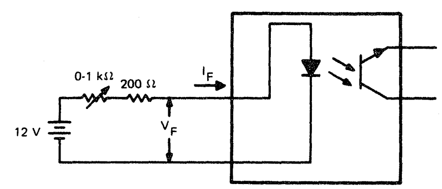
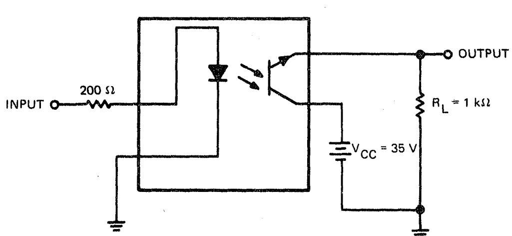
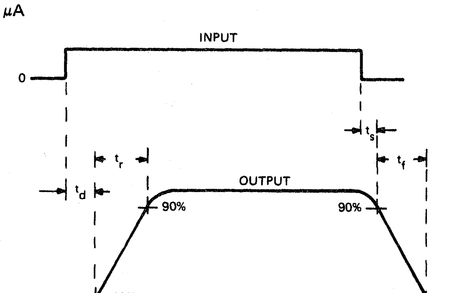


FIGURE D—V_F

Adjust amplitude
of input pulse
for $I_{C(on)} = 500\ \mu A$



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE E—SWITCHING TIMES

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leqslant 100$ ns, $t_w = 50\ \mu s$, duty cycle ≈ 50%.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leqslant 12$ ns, $R_{in} \geqslant 1\ M\Omega$, $C_{in} \leqslant 20$ pF.

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BULLETIN NO. DL-S 7411572, SEPTEMBER 1971–REVISED NOVEMBER 1974

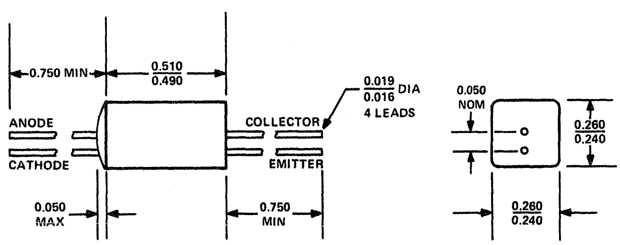
GALLIUM ARSENIDE DIODE INFRARED SOURCE OPTICALLY COUPLED TO A SILICON N-P-N PHOTOTRANSISTOR

- **Ideal for Electrical Isolation and Relay Replacement in High-Vibration Applications**
- **Provides High-Voltage Electrical Isolation: 5-kV Rating**
- **Output Current: 250 μA Min, 1500 μA Typ**
- **Stable over a Wide Temperature Range**
- **High-Speed Switching: t_r = 5 μs, t_f = 5 μs Typ**

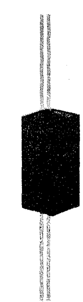
5

mechanical data

These devices are mounted in a precast epoxy shell which is filled and sealed with epoxy to produce a solid assembly. The case will withstand soldering temperature without deformation. The assembly is insensitive to light.



NOTES: A. Red end indicates input diode terminals.
B. All dimensions are in inches.



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Input-to-Output Voltage	±5 kV
Collector-Emitter Voltage	15 V
Emitter-Collector Voltage	5 V
Input Diode Reverse Voltage	2 V
Input Diode Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	50 mA
Continuous Total Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	150 mW
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 100°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.91 mA/°C.
2. Derate linearly to 80°C free-air temperature the the rate of 2.73 mW/°C. In these devices, a significant portion of the dissipation is in the input diode. $P_T = V_{CE} I_C + V_F I_F$.

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$, $I_F = 0$	15			V
$I_{C(on)}$	On-State Collector Current	$V_{CE} = 5\ V$, $I_F = 35\ mA$	250	1500		µA
$I_{C(off)}$	Off-State Collector Current	$V_{CE} = 5\ V$, $I_F = 0$			500	nA
		$V_{CE} = 5\ V$, $I_F = 0$, $T_A = 80°C$		10		µA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_F = 15\ mA$, $I_C = 125\ \mu A$			0.3	V
V_F	Input Diode Static Forward Voltage	$I_F = 35\ mA$		1.2	1.9	V
r_{IO}	Input-to-Output Internal Resistance	$V_{in\text{-}out} = \pm 5\ kV$, See Note 3		$> 10^{13}$		Ω

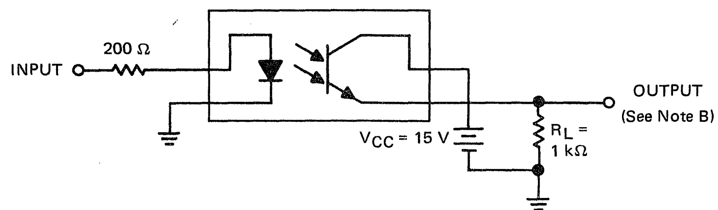
NOTE 3: This parameter is measured between both input diode leads shorted together and both phototransistor leads shorted together.

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS		TYP	UNIT
t_r	Rise Time	$V_{CC} = 15\ V$,	$I_{C(on)} = 250\ \mu A$,	5	µs
t_f	Fall Time	$R_L = 1\ k\Omega$,	See Figure 1	5	µs

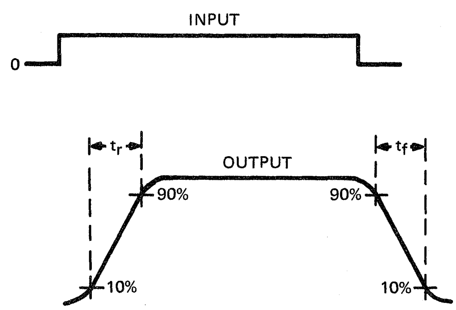
5

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

Adjust amplitude
of input pulse
for $I_{C(on)} = 250\ \mu A$



VOLTAGE WAVEFORMS

FIGURE 1—SWITCHING TIMES

NOTES: A. The input waveform is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leqslant 100$ ns, $t_w = 50\ \mu s$, duty cycle ≈ 50%.

B. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant 12$ ns, $R_{in} \geqslant 1\ M\Omega$, $C_{in} \leqslant 20$ pF.

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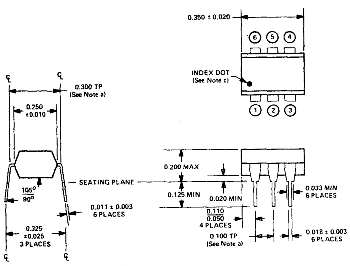
COMPATABLE WITH STANDARD DTL AND TTL INTEGRATED CIRCUITS

- **Gallium Arsenide Diode Infrared Source Optically Coupled to a Silicon N-P-N Phototransistor**
- **High Direct-Current Transfer Ratio**
- **Base Lead Provided for Conventional Transistor Biasing**
- **High-Voltage Electrical Isolation . . . 1.5-kV or 2.5-kV Rating**
- **Plastic Dual-In-Line Package**
- **High-Speed Switching: t_r = 2 μs, t_f = 2 μs Typical**

5

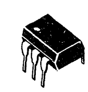
mechanical data

The package consists of a gallium arsenide infrared-emitting diode and an n-p-n silicon phototransistor mounted on a 6-lead frame encapsulated within an electrically nonconductive plastic compound. The case will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Unit weight is approximately 0.52 grams.



NOTES:

a. Leads are within 0.005 radius of true position (TP) at the gauge plane with maximum material condition and unit installed.
b. All dimensions are in inches unless otherwise noted.
c. Pin 1 identified by index dot.
d. Terminal connections:
   1. Anode } Infrared-emitting diode
   2. Cathode
   3. No internal connection
   4. Emitter } Phototransistor
   5. Collector
   6. Base



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Input-to-Output Voltage: TIL111	±1.5 kV
TIL114, TIL116, TIL117	±2.5 kV
Collector-Base Voltage	70 V
Collector-Emitter Voltage (See Note 1)	30 V
Emitter-Collector Voltage	7 V
Emitter-Base Voltage	7 V
Input-Diode Reverse Voltage	3 V
Input-Diode Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 2)	100 mA
Continuous Power Dissipation at (or below) 25°C Free-Air Temperature:	
Infrared-Emitting Diode (See Note 3)	150 mW
Phototransistor (See Note 4)	150 mW
Total, Infrared-Emitting Diode plus Phototransistor (See Note 5)	250 mW
Storage Temperature Range	–55°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES:
1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 100°C free-air temperature at the rate of 1.33 mA/°C.
3. Derate linearly to 100°C free-air temperature at the rate of 2 mW/°C.
4. Derate linearly to 100°C free-air temperature at the rate of 2 mW/°C.
5. Derate linearly to 100°C free-air temperature at the rate of 3.33 mW/°C.

electrical characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	TIL111 TIL114			TIL116			TIL117			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage		$I_C = 10\ \mu A$, $I_E = 0$, $I_F = 0$	70			70			70			V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage		$I_C = 1\ mA$, $I_B = 0$, $I_F = 0$	30			30			30			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage		$I_E = 10\ \mu A$, $I_C = 0$, $I_F = 0$	7			7			7			V
I_R	Input Diode Static Reverse Current		$V_R = 3\ V$			10			10			10	µA
$I_{C(on)}$	On-State Collector Current	Phototransistor Operation	$V_{CE} = 0.4\ V$, $I_F = 16\ mA$, $I_B = 0$	2	7								mA
			$V_{CE} = 10\ V$, $I_F = 10\ mA$, $I_B = 0$				2	5		5	9		
		Photodiode Operation	$V_{CB} = 0.4\ V$, $I_F = 16\ mA$, $I_E = 0$	10	20		10	20		10	20		µA
$I_{C(off)}$	Off-State Collector Current	Phototransistor Operation	$V_{CE} = 10\ V$, $I_F = 0$, $I_B = 0$		1	50		1	50		1	50	nA
		Photodiode Operation	$V_{CB} = 10\ V$, $I_F = 0$, $I_E = 0$		0.1	20		0.1	20		0.1	20	
h_{FE}	Transistor Static Forward Current Transfer Ratio		$V_{CE} = 5\ V$, $I_C = 10\ mA$, $I_F = 0$	100	300					200	550		
			$V_{CE} = 5\ V$, $I_C = 100\ \mu A$, $I_F = 0$				100	300					
V_F	Input Diode Static Forward Voltage		$I_F = 16\ mA$		1.2	1.4					1.2	1.4	V
			$I_F = 60\ mA$					1.25	1.5				
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage		$I_C = 2\ mA$, $I_F = 16\ mA$, $I_B = 0$		0.25	0.4							V
			$I_C = 2.2\ mA$, $I_F = 15\ mA$, $I_B = 0$					0.25	0.4				
			$I_C = 0.5\ mA$, $I_F = 10\ mA$, $I_B = 0$								0.25	0.4	
r_{IO}	Input-to-Output Internal Resistance		$V_{in-out} = \pm 1.5\ kV$ for TIL111, $\pm 2.5\ kV$ for all others, See Note 6	10^{11}			10^{11}			10^{11}			Ω
C_{io}	Input-to-Output Capacitance		$V_{in-out} = 0$, $f = 1\ MHz$, See Note 6		1	1.3		1	1.3		1	1.3	pF

NOTE 6: These parameters are measured between both input-diode leads shorted together and all the phototransistor leads shorted together.

switching characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	TIL111 TIL114			TIL116			TIL117			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
t_r	Rise Time	Phototransistor Operation	$V_{CC} = 10\ V$, $I_{C(on)} = 2\ mA$, $R_L = 100\ \Omega$, See Test Circuit A of Figure 1		2	5		2	7		2	9	µs
t_f	Fall Time				2	5		2	7		2	9	
t_r	Rise Time	Photodiode Operation	$V_{CC} = 10\ V$, $I_{C(on)} = 20\ \mu A$, $R_L = 1\ k\Omega$, See Test Circuit B of Figure 1		1			1			1		µs
t_f	Fall Time				1			1			1		

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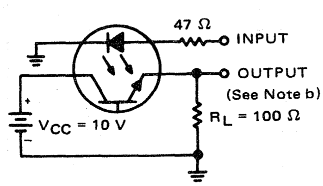
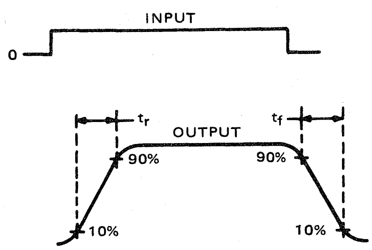
PARAMETER MEASUREMENT INFORMATION

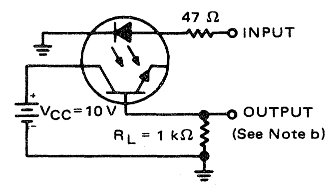
Adjust amplitude of input pulse for:
$I_{C(on)}$ = 2 mA (Test Circuit A) or
$I_{C(on)}$ = 20 μA (Test Circuit B)



TEST CIRCUIT A
PHOTOTRANSISTOR OPERATION



VOLTAGE WAVEFORMS



TEST CIRCUIT B
PHOTODIODE OPERATION

NOTES: a. The input waveform is supplied by a generator with the following characteristics: Z_{out} = 50 Ω, $t_r \leqslant$ 15 ns, duty cycle ≈ 1%, t_w = 100 μs.
b. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leqslant$ 12 ns, $R_{in} \geqslant$ 1 MΩ, $C_{in} \leqslant$ 20 pF.

FIGURE 1—SWITCHING TIMES

TYPICAL CHARACTERISTICS

TIL111, TIL114

COLLECTOR CURRENT
vs
INPUT-DIODE FORWARD CURRENT

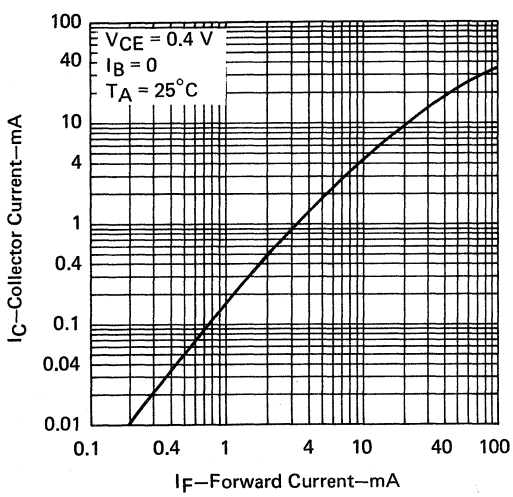


FIGURE 2

TIL116, TIL117

COLLECTOR CURRENT
vs
INPUT-DIODE FORWARD CURRENT

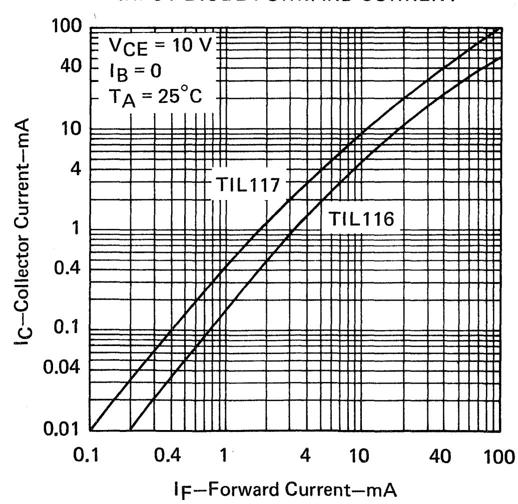


FIGURE 3

TYPICAL CHARACTERISTICS

TIL111, TIL114

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

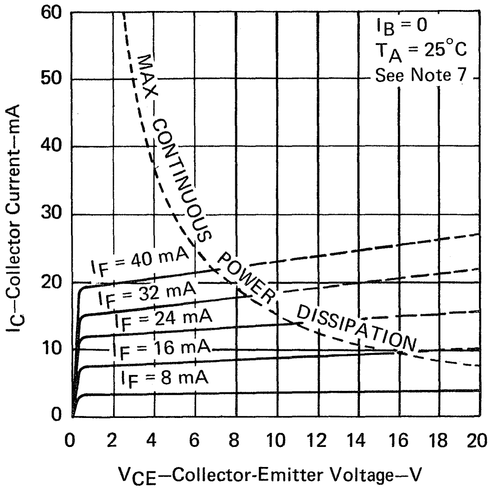


FIGURE 4

TIL116

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

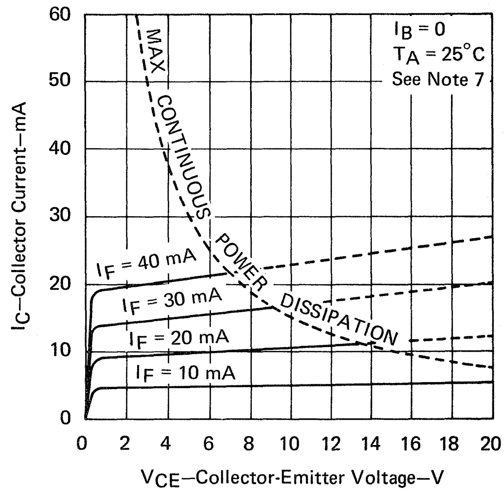


FIGURE 5

TIL117

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

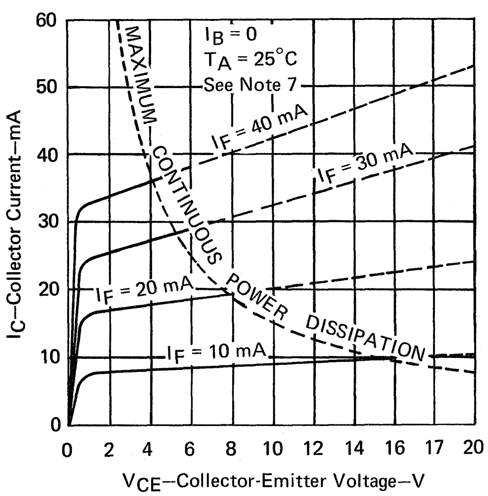


FIGURE 6

RELATIVE ON-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

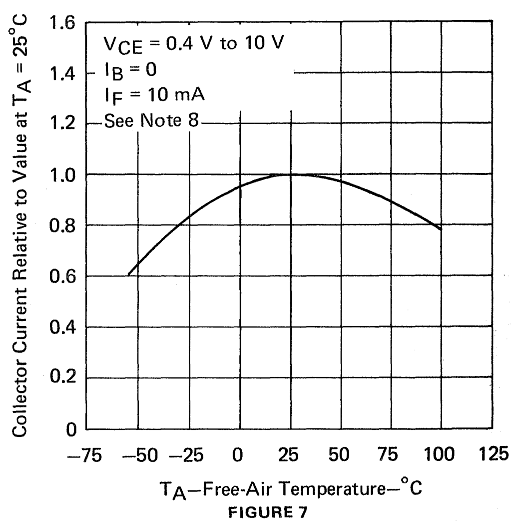


FIGURE 7

NOTES: 7. Pulse operation of input diode is required for operation beyond limits shown by dotted lines.
8. These parameters were measured using pulse techniques. $t_w = 1$ ms, duty cycle $\leq 2\%$.

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TYPICAL CHARACTERISTICS

OFF-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

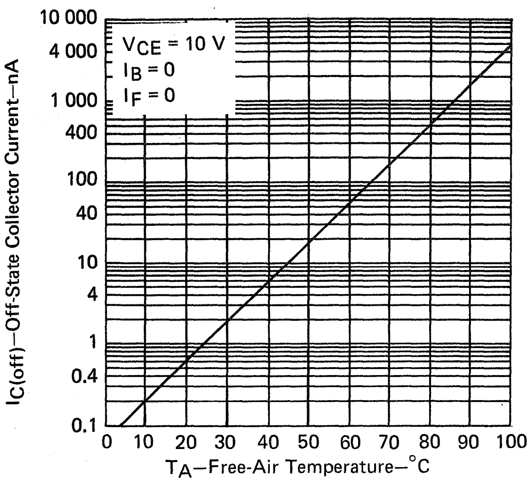

FIGURE 8

NORMALIZED TRANSISTOR STATIC FORWARD
CURRENT TRANSFER RATIO
vs
ON-STATE COLLECTOR CURRENT

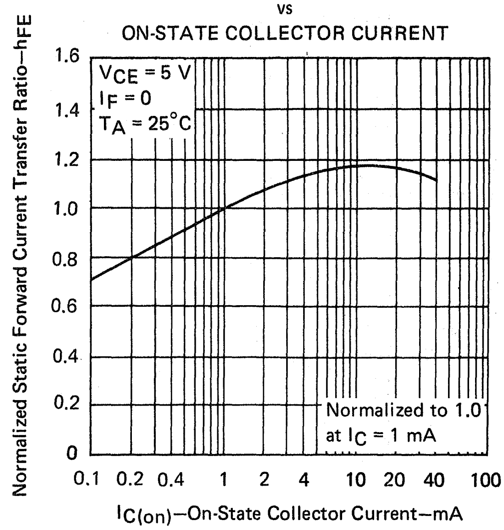

FIGURE 9

INPUT DIODE FORWARD
CONDUCTION CHARACTERISTICS

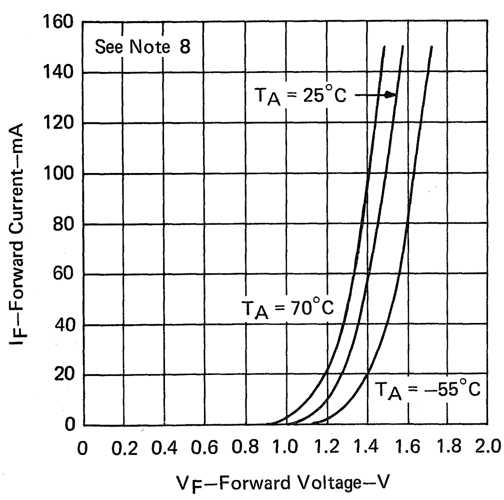

FIGURE 10

COLLECTOR CURRENT
vs
MODULATION FREQUENCY

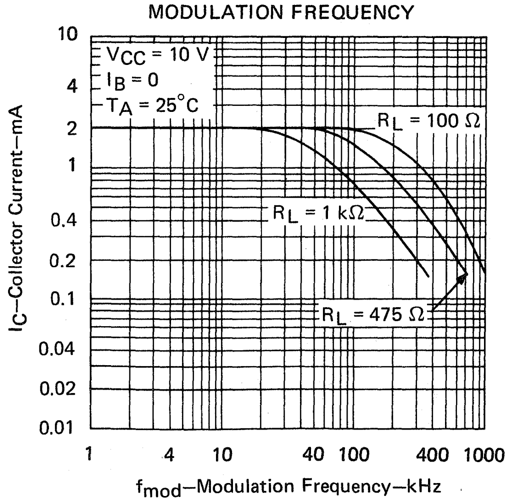

FIGURE 11

NOTE 8: These parameters were measured using pulse techniques. t_w = 1 ms, duty cycle ⩽ 2%.

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BULLETIN NO. DL-S 7312031, NOVEMBER 1973

- **Gallium Arsenide Diode Infrared Source Optically Coupled to a Silicon N-P-N Phototransistor**
- **High Direct-Current Transfer Ratio**
- **Base Lead Provided for Conventional Transistor Biasing (TIL112, TIL115)**
- **High-Voltage Electrical Isolation . . . 1.5-kV or 2.5-kV Rating**
- **Plastic Dual-In-Line Package**
- **High-Speed Switching: t_r = 2 μs, t_f = 2 μs Typical**

mechanical data

The package consists of a gallium arsenide infrared-emitting diode and an n-p-n silicon phototransistor mounted on a 6-lead frame encapsulated within an electrically nonconductive plastic compound. The case will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Unit weight is approximately 0.52 grams.

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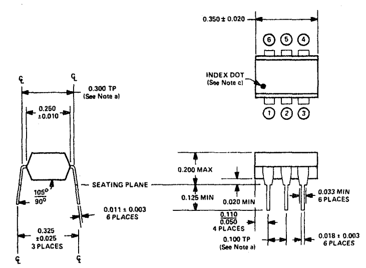

NOTES:
a. Leads are within 0.005 radius of true position (TP) at the gauge plane with maximum material condition and unit installed.
b. All dimensions are in inches unless otherwise noted.
c. Pin 1 identified by index dot.
d. Terminal connections:
1. Anode } Infrared-emitting
2. Cathode } diode
3. No internal connection
4. Emitter }
5. Collector } Phototransistor
6. Base (For TIL118, make no external connection) }

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

	TIL112	TIL115	TIL118
Input-to-Output Voltage	±1.5 kV	±2.5 kV	±1.5 kV
Collector-Base Voltage	30 V	30 V	
Collector-Emitter Voltage (See Note 1)	20 V	20 V	20 V
Emitter-Collector Voltage	4 V	4 V	4 V
Emitter-Base Voltage	4 V	4 V	
Input-Diode Reverse Voltage	3 V	3 V	3 V
Input-Diode Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 2)	← 100 mA →		
Continuous Power Dissipation at (or below) 25°C Free-Air Temperature:			
Infrared-Emitting Diode (See Note 3)	← 150 mW →		
Phototransistor (See Note 4)	← 150 mW →		
Total (Infrared-Emitting Diode plus Phototransistor, See Note 5)	← 250 mW →		
Storage Temperature Range	← −55°C to 150°C →		
Lead Temperature 1/16 Inch from Case for 10 Seconds	← 260°C →		

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 100°C free-air temperature at the rate of 1.33 mA/°C.
3. Derate linearly to 100°C free-air temperature at the rate of 2 mW/°C.
4. Derate linearly to 100°C free-air temperature at the rate of 2 mW/°C.
5. Derate linearly to 100°C free-air temperature at the rate of 3.33 mW/°C.

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electrical characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS†	TIL112			TIL115			TIL118			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage		$I_C = 10\ \mu A$, $I_E = 0$, $I_F = 0$	30			30						V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage		$I_C = 1\ mA$, $I_B = 0$, $I_F = 0$	20			20			20			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage		$I_E = 10\ \mu A$, $I_C = 0$, $I_F = 0$	4			4						V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage		$I_E = 10\ \mu A$, $I_F = 0$							4			V
$I_{C(on)}$	On-State Collector Current	Phototransistor Operation	$V_{CE} = 5\ V$, $I_F = 10\ mA$, $I_B = 0$	0.2	2		0.2	2		1	2		mA
		Photodiode Operation	$V_{CB} = 5\ V$, $I_F = 10\ mA$, $I_E = 0$	2	10		2	10					μA
$I_{C(off)}$	Off-State Collector Current	Phototransistor Operation	$V_{CE} = 5\ V$, $I_F = 0$, $I_B = 0$		1	100		1	100		1	100	nA
		Photodiode Operation	$V_{CB} = 5\ V$, $I_F = 0$, $I_E = 0$		0.1	50		0.1	50				
h_{FE}	Transistor Static Forward Current Transfer Ratio		$V_{CE} = 5\ V$, $I_C = 10\ mA$, $I_F = 0$	50	200		50	200					
V_F	Input Diode Static Forward Voltage		$I_F = 10\ mA$		1.2	1.5		1.2	1.5		1.2	1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage		$I_C = 2\ mA$, $I_F = 50\ mA$, $I_B = 0$			0.5			0.5			0.5	V
r_{IO}	Input-to-Output Internal Resistance		$V_{in-out} = \pm 1.5\ kV$, See Note 6	10^{11}						10^{11}			Ω
			$V_{in-out} = \pm 2.5\ kV$, See Note 6				10^{11}						
C_{io}	Input-to-Output Capacitance		$V_{in-out} = 0$, $f = 1\ MHz$, See Note 6		1	2		1	2		1	2	pF

NOTE 6: These parameters are measured between both input-diode leads shorted together and all the phototransistor leads shorted together.
†References to the base are not applicable for the TIL118.

switching characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	TIL112			TIL115			TIL118			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
t_r	Rise Time	Phototransistor Operation	$V_{CC} = 10\ V$, $I_{C(on)} = 2\ mA$, $R_L = 100\ \Omega$, See Test Circuit A of Figure 1		2	15		2	15		2	15	μs
t_f	Fall Time				2	15		2	15		2	15	
t_r	Rise Time	Photodiode Operation	$V_{CC} = 10\ V$, $I_{C(on)} = 20\ \mu A$, $R_L = 1\ k\Omega$, See Test Circuit B of Figure 1		1			1					μs
t_f	Fall Time				1			1					

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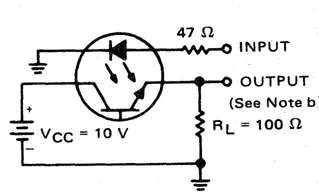
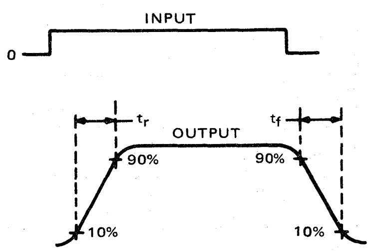
PARAMETER MEASUREMENT INFORMATION

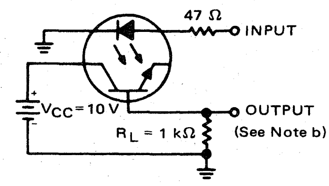
Adjust amplitude of input pulse for:
$I_{C(on)}$ = 2 mA (Test Circuit A) or
$I_{C(on)}$ = 20 μA (Test Circuit B)



TEST CIRCUIT A
PHOTOTRANSISTOR OPERATION



VOLTAGE WAVEFORMS



TEST CIRCUIT B
PHOTODIODE OPERATION

NOTES: a. The input waveform is supplied by a generator with the following characteristics: Z_{out} = 50 Ω, $t_r \leq$ 15 ns, duty cycle ≈ 1%, t_w = 100 μs.
b. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq$ 12 ns, $R_{in} \geq$ 1 MΩ, $C_{in} \leq$ 20 pF.

FIGURE 1–SWITCHING TIMES

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TYPICAL CHARACTERISTICS

COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

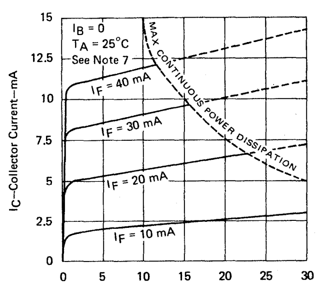

FIGURE 2

COLLECTOR CURRENT
vs
INPUT-DIODE FORWARD CURRENT

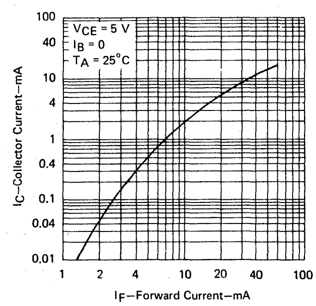

FIGURE 3

RELATIVE ON-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

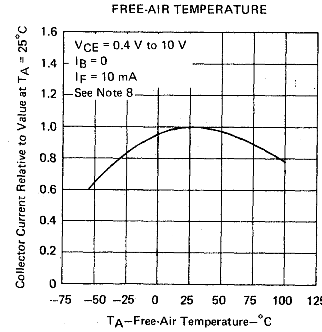

FIGURE 4

NOTES: 7. Pulse operation of input diode is required for operation beyond limits shown by dotted lines.
8. These parameters were measured using pulse techniques t_w = 1 ms, duty cycle ≤ 2%.

TYPICAL CHARACTERISTICS

OFF-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

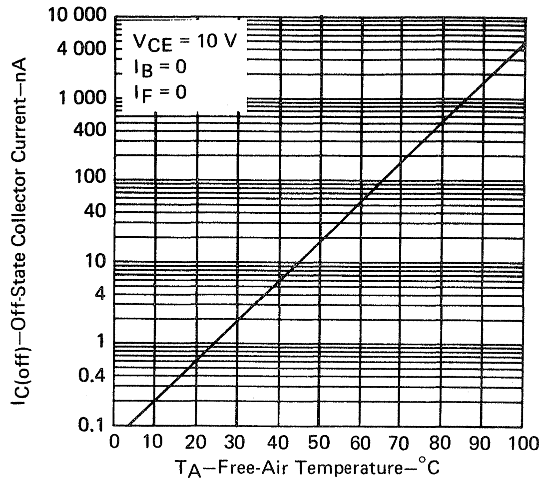

FIGURE 5

NORMALIZED TRANSISTOR STATIC FORWARD
CURRENT TRANSFER RATIO
vs
ON-STATE COLLECTOR CURRENT

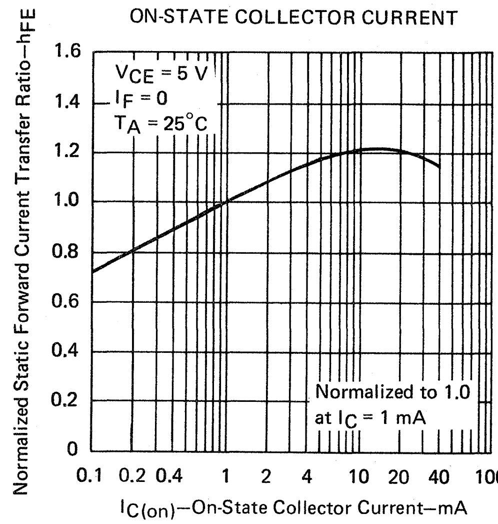

FIGURE 6

INPUT DIODE FORWARD
CONDUCTION CHARACTERISTICS

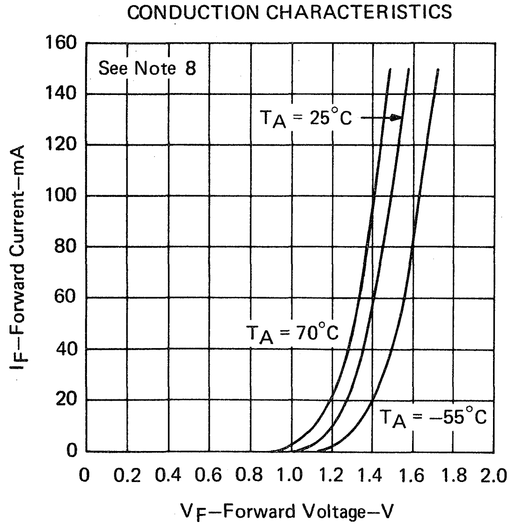

FIGURE 7

COLLECTOR CURRENT
vs
MODULATION FREQUENCY

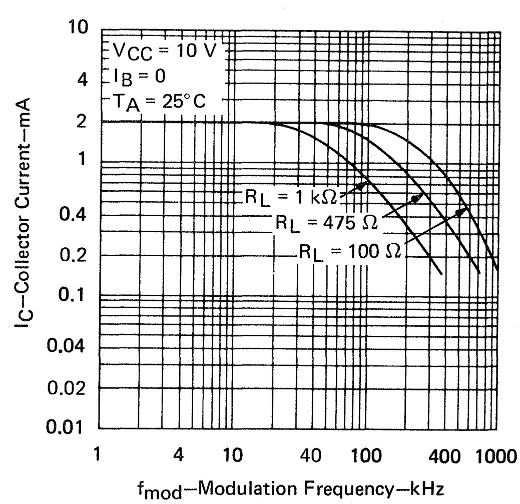

FIGURE 8

NOTE 8: These parameters were measured using pulse techniques. t_w = 1 ms, duty cycle ≤ 2%.

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PRINTED IN U.S.A. 1174

BULLETIN NO. DL-S 7312032, NOVEMBER 1973

- **Gallium Arsenide Diode Infrared Source Optically Coupled to a Silicon N-P-N Darlington-Connected Phototransistor**
- **High Direct-Current Transfer Ratio . . . 300% Minimum at 10 mA**
- **Base Lead Provided for Conventional Transistor Biasing**
- **High-Voltage Electrical Isolation . . . 1500-Volt Rating**
- **Plastic Dual-In-Line Package**
- **Typical Applications Include Remote Terminal Isolation, SCR and Triac Triggers, Mechanical Relays, and Pulse Transformers**

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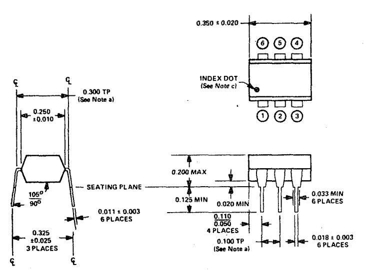
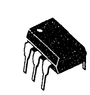
mechanical data

The package consists of a gallium arsenide infrared-emitting diode and an n-p-n silicon darlington-connected phototransistor mounted on a 6-lead frame encapsulated within an electrically nonconductive plastic compound. The case will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high humidity conditions. Unit weight is approximately 0.52 grams.



NOTES:
a. Leads are within 0.005 radius of true position (TP) at the gauge plane with maximum material condition and unit installed.
b. All dimensions are in inches unless otherwise noted.
c. Pin 1 identified by index dot.
d. Terminal connections:
   1. Anode } Infrared-emitting diode
   2. Cathode }
   3. No internal connection
   4. Emitter } Phototransistor
   5. Collector }
   6. Base (For TIL119, make no external connection) }



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Input-to-Output Voltage	±1.5 kV
Collector-Base Voltage (TIL113)	30 V
Collector-Emitter Voltage (See Note 1)	30 V
Emitter-Collector Voltage	7 V
Emitter-Base Voltage (TIL113)	7 V
Input-Diode Reverse Voltage	3 V
Input-Diode Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 2)	100 mA
Continuous Power Dissipation at (or below) 25°C Free-Air Temperature:	
Infrared-Emitting Diode (See Note 3)	150 mW
Phototransistor (See Note 4)	150 mW
Total (Infrared-Emitting Diode plus Phototransistor, See Note 5)	250 mW
Storage Temperature Range	–55°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	260°C

NOTES: 1. This value applies when the base-emitter diode is open-circuited.
2. Derate linearly to 100°C free-air temperature at the rate of 1.33 mA/°C.
3. Derate linearly to 100°C free-air temperature at the rate of 2 mW/°C.
4. Derate linearly to 100°C free-air temperature at the rate of 2 mW/°C.
5. Derate linearly to 100°C free-air temperature at the rate of 3.33 mW/°C.

electrical characteristics at 25° C free-air temperature

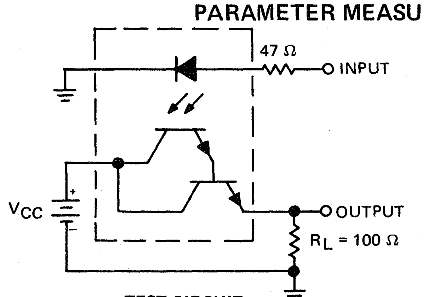
PARAMETER		TEST CONDITIONS†	TIL113 MIN	TIL113 TYP	TIL113 MAX	TIL119 MIN	TIL119 TYP	TIL119 MAX	UNIT
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10\ \mu A$, $I_E = 0$, $I_F = 0$	30						V
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 1$ mA, $I_B = 0$, $I_F = 0$	30			30			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu A$, $I_C = 0$, $I_F = 0$	7						V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 10\ \mu A$, $I_F = 0$				7			V
$I_{C(on)}$	On-State Collector Current	$V_{CE} = 1$ V, $I_B = 0$, $I_F = 10$ mA	30	100					mA
		$V_{CE} = 2$ V, $I_F = 10$ mA				30	160		
$I_{C(off)}$	Off-State Collector Current	$V_{CE} = 10$ V, $I_B = 0$, $I_F = 0$			100			100	nA
h_{FE}	Transistor Static Forward Current Transfer Ratio	$V_{CE} = 1$ V, $I_C = 10$ mA, $I_F = 0$		15,000					
V_F	Input Diode Static Forward Voltage	$I_F = 10$ mA			1.5			1.5	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 125$ mA, $I_B = 0$, $I_F = 50$ mA			1				V
		$I_C = 10$ mA, $I_F = 10$ mA						1	
r_{IO}	Input-to-Output Internal Resistance	$V_{in\text{-}out} = \pm 1.5$ kV, See Note 6	10^{11}			10^{11}			Ω
C_{io}	Input-to-Output Capacitance	$V_{in\text{-}out} = 0$, f = 1 MHz, See Note 6		1	1.3		1	1.3	pF

NOTE 6: These parameters are measured between both input-diode leads shorted together and all the phototransistor leads shorted together.
†References to the base are not applicable to the TIL119.

switching characteristics at 25° C free-air temperature

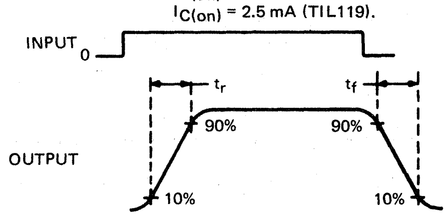
PARAMETER		TEST CONDITIONS	TIL113 MIN	TIL113 TYP	TIL113 MAX	TIL119 MIN	TIL119 TYP	TIL119 MAX	UNIT
t_r	Rise Time	$V_{CC} = 15$ V, $I_{C(on)} = 125$ mA,		50					μs
t_f	Fall Time	$R_L = 100\ \Omega$, See Figure 1		50					
t_r	Rise Time	$V_{CC} = 10$ V, $I_{C(on)} = 2.5$ mA,					50		μs
t_f	Fall Time	$R_L = 100\ \Omega$, See Figure 1					50		

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

Adjust amplitude of input pulse for:
$I_{C(on)} = 125$ mA (TIL113)
$I_{C(on)} = 2.5$ mA (TIL119).



VOLTAGE WAVEFORMS

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 15$ ns, duty cycle ≈ 1%, $t_w = 100\ \mu s$.
b. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 12$ ns, $R_{in} \geq 1\ M\Omega$, $C_{in} \leq 20$ pF.

FIGURE 1—SWITCHING TIMES

TYPICAL CHARACTERISTICS

TIL113
COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

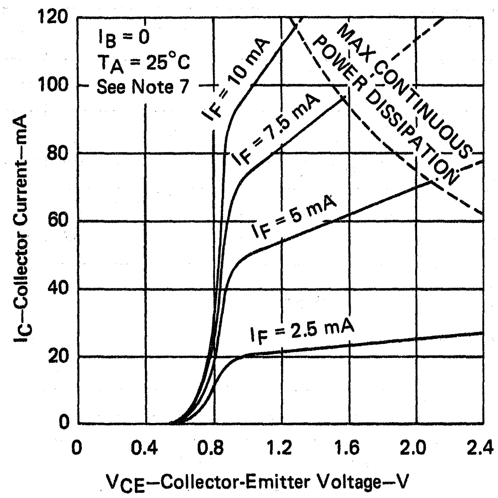


FIGURE 2

TIL119
COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

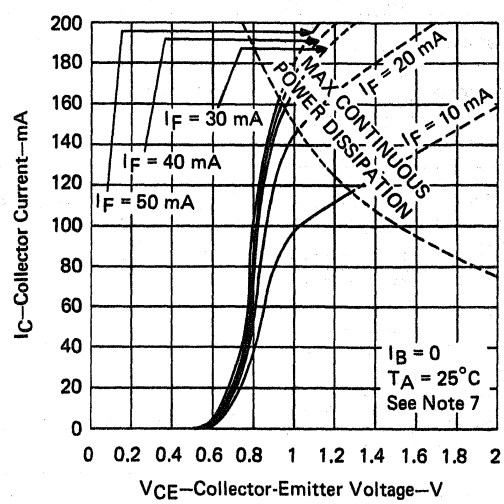


FIGURE 3

TIL113
COLLECTOR CURRENT
vs
INPUT-DIODE FORWARD CURRENT

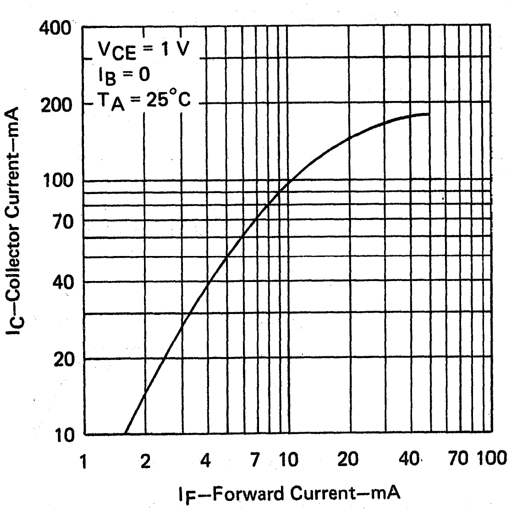


FIGURE 4

OFF-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

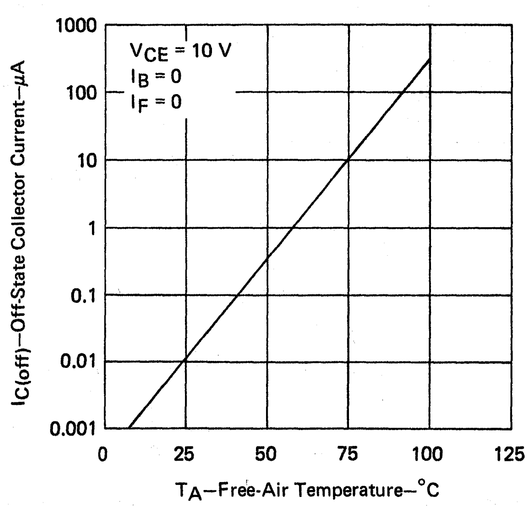


FIGURE 5

NOTE 7: Pulse operation of input diode is required for operation beyond limits shown by dotted line.

TYPICAL CHARACTERISTICS

TIL113
RELATIVE COLLECTOR-EMITTER SATURATION VOLTAGE
vs
FREE-AIR TEMPERATURE

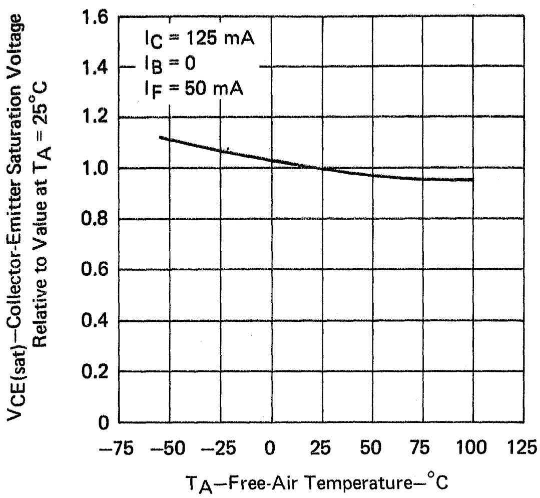


FIGURE 6

TIL113
TRANSISTOR STATIC FORWARD CURRENT TRANSFER RATIO
vs
COLLECTOR CURRENT

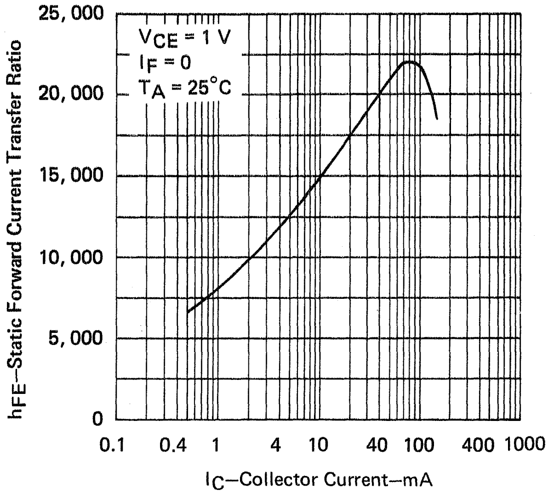


FIGURE 7

INPUT DIODE FORWARD
CONDUCTION CHARACTERISTICS

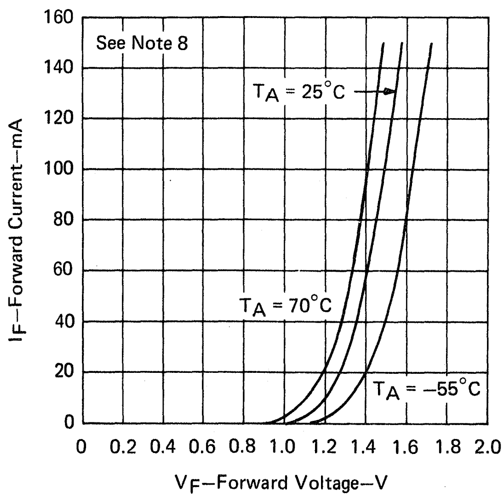


FIGURE 8

NOTE 8: This parameter was measured using pulse techniques. t_w = 1 ms, duty cycle ⩽ 2%.

PRINTED IN U.S.A. 1173

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

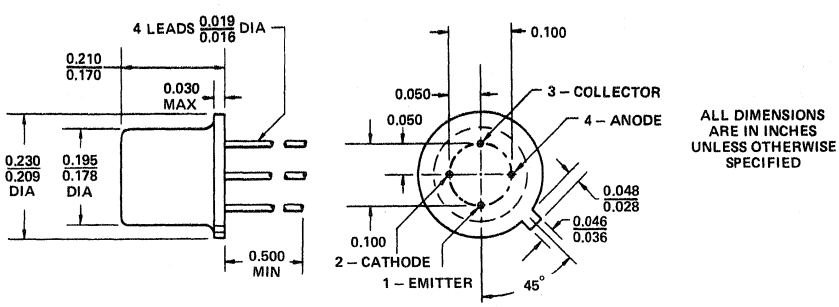
BULLETIN NO. DL-S 7412216, NOVEMBER 1974

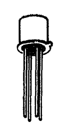
GALLIUM ARSENIDE DIODE INFRARED SOURCE OPTICALLY COUPLED TO A HIGH-GAIN N-P-N SILICON PHOTOTRANSISTOR

- **Photon Coupling for Isolator Applications**
- **High Overall Current Gain . . . 1.0 Typ (TIL121)**
- **High-Gain, High-Voltage Transistor . . . $V_{(BR)CEO}$ = 35 V Min**
- **High-Voltage Electrical Isolation . . . 1-kV Rating**
- **Stable Over Wide Temperature Range**

mechanical data

THE COLLECTOR IS IN ELECTRICAL CONTACT WITH THE CASE





ALL JEDEC TO-72 DIMENSIONS AND NOTES ARE APPLICABLE

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Input-to-Output Voltage	±1 kV
Collector-Emitter Voltage	35 V
Emitter-Collector Voltage	7 V
Input Diode Reverse Voltage	3 V
Input Diode Continuous Forward Current at (or below) 65°C Free-Air Temperature (See Note 1)	40 mA
Continuous Collector Current	50 mA
Continuous Transistor Power Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	190 mW
Operating Free-Air Temperature Range	−55°C to 125°C
Storage Temperature Range	−55°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	240°C

NOTES: 1. Derate linearly to 125°C free-air temperature at the rate of 0.67 mA/°C.
2. Derate linearly to 125°C free-air temperature at the rate of 1.9 mW/°C.

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS		TIL120			TIL121			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 1 mA,	I_F = 0	35			35			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	I_E = 100 μA,	I_F = 0	7			7			V
I_R	Input Diode Static Reverse Current	V_R = 3 V				100			100	μA
$I_{C(on)}$	On-State Collector Current	V_{CE} = 5 V,	I_F = 10 mA	2.5	6		5	10		mA
$I_{C(off)}$	Off-State Collector Current	V_{CE} = 20 V,	I_F = 0		6	100		6	100	nA
		V_{CE} = 20 V, T_A = 100°C	I_F = 0,		4			4		μA
V_F	Input Diode Static Forward Voltage	I_F = 10 mA				1.3			1.3	V
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 2.5 mA,	I_F = 20 mA			0.3				V
		I_C = 10 mA,	I_F = 20 mA						0.3	
r_{io}	Input-to-Output Internal Resistance	V_{in-out} = ±1 kV,	See Note 3	10^{11}	10^{12}		10^{11}	10^{12}		Ω
C_{io}	Input-to-Output Capacitance	V_{in-out} = 0, See Note 3	f = 1 MHz,		2.5			2.5		pF

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NOTE 3: These parameters are measured between both input diode leads shorted together and both phototransistor leads shorted together.

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS		TIL120			TIL121			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
t_r	Rise Time	V_{CC} = 20 V,	$I_{C(on)}$ = 5 mA		3	20		6	20	μs
t_f	Fall Time	R_L = 100 Ω,	See Figure 1		3	20		6	20	μs

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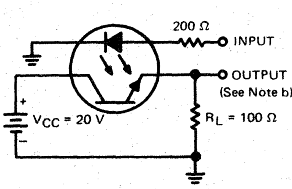
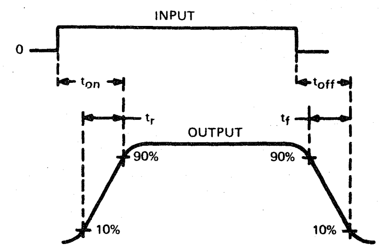
PARAMETER MEASUREMENT INFORMATION

Adjust amplitude of input pulse for $I_{C(on)} = 5$ mA



TEST CIRCUIT



VOLTAGE WAVEFORMS

NOTES: a. The input waveform is supplied by a generator with the following characteristics: $z_{out} = 50\ \Omega$, $t_r \leq 15$ ns, duty cycle ≈ 1%, $t_w = 100\ \mu s$.

b. Waveforms are monitored on an oscilloscope with the following characteristics: $t_r \leq 12$ ns, $R_{in} \geq 1\ M\Omega$, $C_{in} \leq 20$ pF.

FIGURE 1—SWITCHING TIMES

TYPICAL CHARACTERISTICS

TIL120
COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

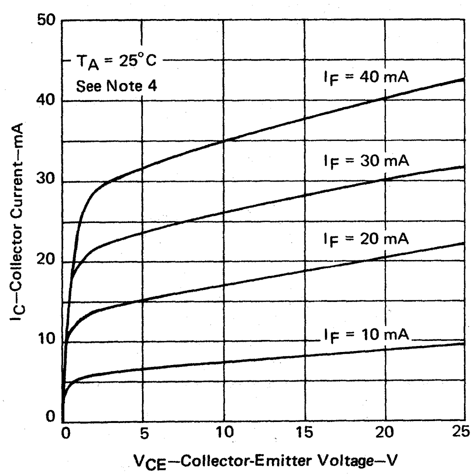


FIGURE 2

TIL121
COLLECTOR CURRENT
vs
COLLECTOR-EMITTER VOLTAGE

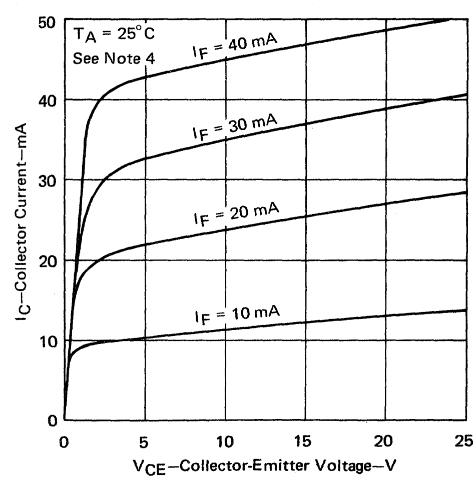


FIGURE 3

NOTE 4: This parameter was measured using pulse techniques. $t_w = 100\ \mu s$, duty cycle = 1%.

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TYPICAL CHARACTERISTICS

INPUT DIODE FORWARD CONDUCTION CHARACTERISTICS

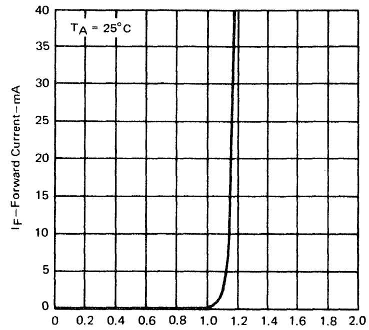

FIGURE 4

NORMALIZED ON-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

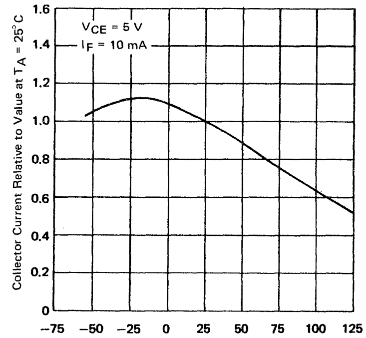

FIGURE 5

PHOTOTRANSISTOR COLLECTOR CURRENT
vs
INPUT-DIODE FORWARD CURRENT

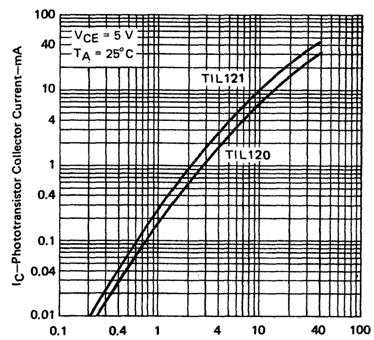

FIGURE 6

OFF-STATE COLLECTOR CURRENT
vs
FREE-AIR TEMPERATURE

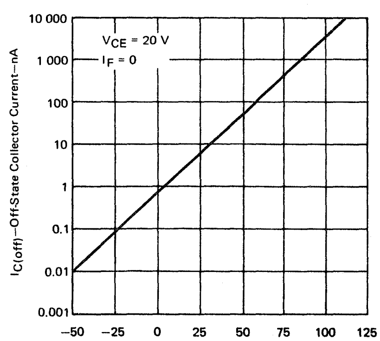

FIGURE 7

TIL120
AVERAGE SWITCHING TIME
vs
LOAD RESISTANCE

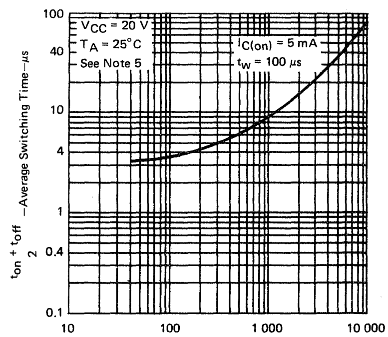

FIGURE 8

NOTE 5: These parameters were measured in the test circuit of Figure 1 with R_L varied between 40 Ω and 10 kΩ.

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OPTO-COUPLERS IN CIRCUITS

Howard T. Russell

There are many situations in which information must be transmitted between switching circuits electrically isolated from each other. This isolation has been commonly provided by relays, isolation transformers, and line drivers and receivers. There is, however, another device that can be used quite effectively to solve these problems. This device is the opto-coupler. The need for the opto-coupler is most prominent in areas where high voltage and noise isolation, as well as small size, are considered important. By coupling two systems together with the transmission of radiant energy (photons), the necessity for a common ground is eliminated – the main purpose of the opto-coupler – and the systems can be effectively isolated.

Four Texas Instruments opto-coupler devices, the TIL102, TIL103, TIL107, and TIL108, are discussed in this report. How these devices can be used in various circuits to provide proper isolation in many systems will be a key part of this discussion. There are many circuit applications for opto-couplers; however, the ones offered in this report are just several which can be of special use. Complete specifications for these devices are not included here but are available in data-sheet form.

DESCRIPTION OF AN OPTO-COUPLER

Basically, a Texas Instruments opto-coupler consists of a GaAs (gallium arsenide) infrared-emitting diode (IRED) as the input stage and a silicon n-p-n phototransistor as the output stage. The coupling medium between diode and sensor is either an infrared-transmitting ("IR") glass, as used in the TIL102/TIL103, or simply a gas-filled gap, as used in the TIL107/TIL108. Photons emitted from the diode (emitter) have wavelengths of about 0.9 microns. The sensor transistor responds most efficiently to photons having this same wavelength. Consequently, the input and output devices are spectrally matched for optimum transfer characteristics.

Equivalent circuits for the TIL102/TIL103 and TIL107/TIL108 are shown in Figures 1 and 2. For both families of devices, a current source between the collector and base of the sensor is used to represent the virtual base current generated by incident photons striking the base. This base current is proportional to the amount of radiation emitted from the diode. The collector-base and base-emitter junction capacitances are shown for both devices since they are used to determine the rise and fall times of the output

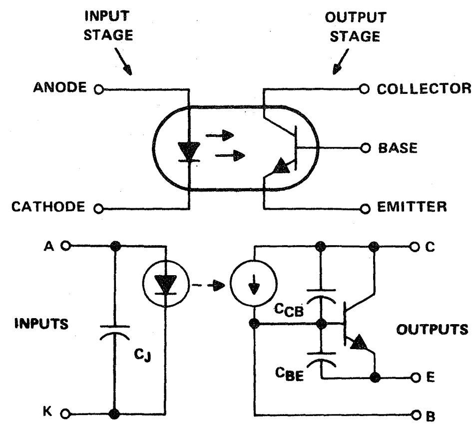

FIGURE 1. Terminal Connections and Equivalent Circuit for the TIL102/TIL103

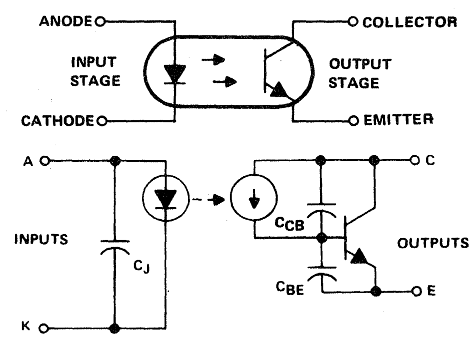

FIGURE 2. Terminal Connections and Equivalent Circuit for the TIL107/TIL108

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current waveform. Because a relatively large transistor base area is necessary for increased sensor efficiency, the collector-base junction capacitance is fairly large.

CHARACTERISTICS OF AN OPTO-COUPLER

To fully utilize the advantages offered by an opto-coupler, it is necessary that the circuit designer become aware of some of its characteristics. The difference in characteristics between the families is attributed mainly to the difference in construction.

The characteristics most useful to the designer are as follows:

1. *High-voltage isolation.* High-voltage isolation between the inputs and outputs is obtained by the physical separation between emitter and sensor. This isolation is possibly the most important advantage of the opto-coupler. These devices can withstand large potential differences, depending on the type of coupling medium and construction of the package. The IR glass separating the emitter and sensor in the TIL102/TIL103 has an isolation capability of 1000 V. In the TIL107/TIL108, the gas-filled (nitrogen) gap limits the breakdown to 1000 V. For both devices, the leakage resistance is greater than $10^{12}\Omega$.
2. *Noise isolation.* Electrical noise in digital signals received at the input of the opto-coupler is isolated from the output by the coupling medium. Since the input is a diode, common-mode noise is rejected. Noise immunity for both devices is less than 1.0 V from anode to cathode.
3. *Current gain.* The current gain (output current/input current) of an opto-coupler is largely determined by the efficiency of the n-p-n sensor and by the type of transmission medium used. For the TIL103, the current gain is greater than unity, which in many cases eliminates the need for current amplifiers in the output. However, both the TIL102/TIL103 and TIL107/TIL108 have output current levels that are compatible with inputs of digital integrated circuits such as 54/74 TTL and DTL. Figures 3 and 4 show typical input-to-output current relationships.
4. *Small size.* The dimensions of these devices enable them to be used on standard printed-wiring boards. The TIL102 and TIL103 are built in a metal can similar to a transistor package while the TIL107 and TIL108 are made into a double-flanged package similar to two TO-18 transistor packages end to end. The physical dimensions of these packages are shown in Figures 5 and 6.

These are some of the prime characteristics of an opto-coupler that can be used effectively to isolate two systems. Other characteristics, such as high speed (which enable opto-couplers to be of advantage in solid-state relays) and wide operating temperature range, are discussed in Texas Instruments Bulletin CB-116 (available upon request).

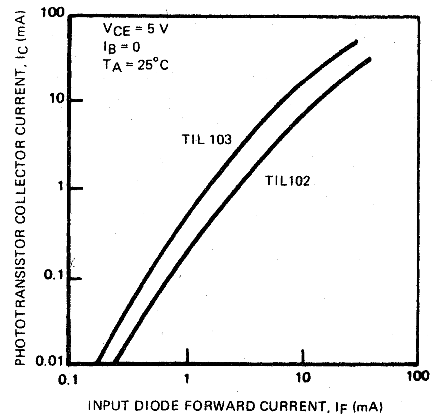

FIGURE 3. Typical Input/Output Current Relationship for the TIL102/TIL103

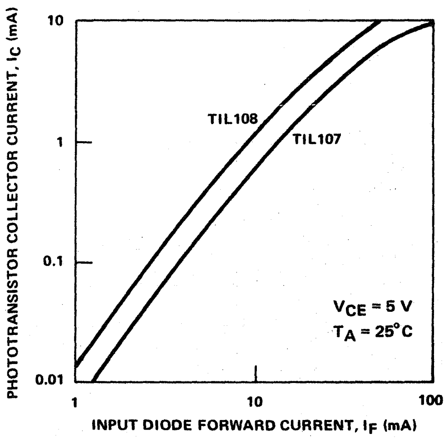

FIGURE 4. Typical Input/Output Current Relationship for the TIL107/TIL108

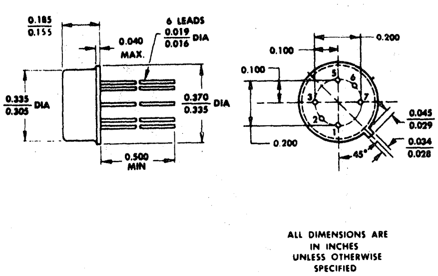

FIGURE 5. Dimensions of the TIL102/TIL103

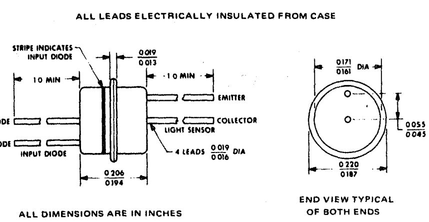

FIGURE 6. Dimensions of the TIL107/TIL108

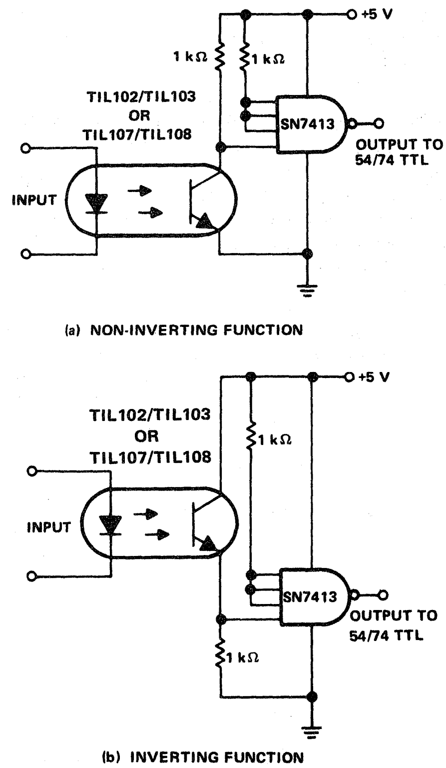

FIGURE 7. Schmitt Trigger Coupling Opto-Coupler to 54/74 TTL Inputs

TYPICAL CIRCUIT APPLICATIONS

The characteristics and advantages of an opto-coupler enable the designer to use it in a wide range of circuit applications. Important among the applications of an opto-coupler are those involving 54/74 TTL and similar digital integrated-circuit families. As was mentioned previously, an opto-coupler has output currents compatible with both DTL and TTL inputs. This compatibility enables it to be especially attractive as an interface element between digital systems. The device is particularly beneficial in applications where high voltage differences may exist between systems. However, it is not limited only to digital applications, as shown by the following examples.

Driving 54/74 TTL

An effective method of coupling an opto-coupler to TTL circuitry is by using a Schmitt trigger that has an output level compatible with standard TTL devices. By coupling any of the Texas Instruments opto-couplers to the SN7413, as shown in Figure 7, the isolated signal at the input can be converted to TTL logic levels. Noise immunity is provided by the coupler as well as by the threshold level of the SN7413.

The opto-coupler can also be employed as part of a Schmitt trigger circuit that utilizes discrete components. Because the output of the opto-coupler is a transistor, it can be used as the input stage to the trigger as shown in Figure 8. For this circuit, regeneration or positive feedback is provided by the coupled emitters of T1 and T2. The output of this circuit is non-inverting and is compatible with TTL logic.

Another Schmitt trigger utilizing discrete components that makes use of the base connection of the TIL102/TIL103 is shown in Figure 9. In this circuit, positive feedback is provided from the collector of T2 to the base of T1. Resistor R1 limits the base current to T1 and keeps the device *off* when there is no signal at the emitter. As with the circuit in Figure 8, the output of this circuit is non-inverting and compatible with TTL levels.

Transmission-Line Isolator

By using an opto-coupler between two systems coupled by a transmission line, effective line isolation can be achieved. Figure 10 shows a typical interface system using TTL integrated circuitry coupled by a twisted-pair

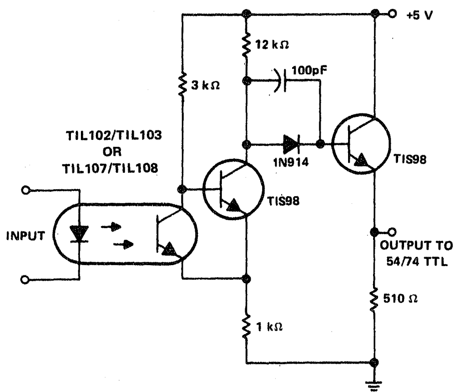

FIGURE 8. Opto-Coupler with Discrete-Component Schmitt Trigger for Driving 54/74 TTL

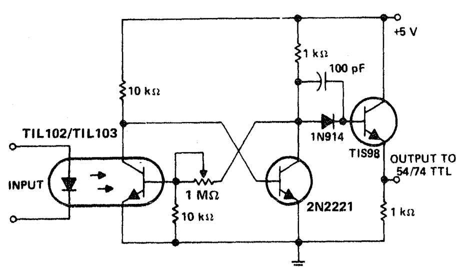

FIGURE 9. TIL102/TIL103 in a Schmitt Trigger for Driving 54/74 TTL

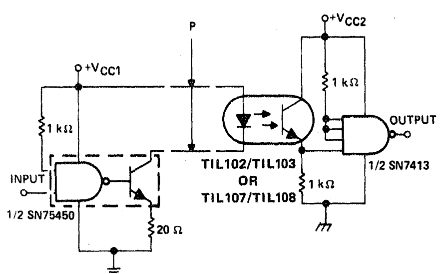

FIGURE 10. Typical Transmission Line Isolator

line. The SN75450B is the input stage driving the transmission line and emitter of the opto-coupler. The IRED requires about 20 mA during "turn-on", which is well below the maximum current rating of the transistor. At the receiving end of the line, the phototransistor is coupled to an SN7413 for fast pulse generation. The output of this system is a non-inverted pulse. However, by rearranging the opto-coupler and the SN7413 as shown in Figure 7(a), the output may be inverted.

As simple as it seems, employing an opto-coupler this way provides isolation for both noise and high voltage. An isolation transformer or relay could accomplish the task, but it would not be as fast as the opto-coupler. Also, a line driver and receiver combination could be used to eliminate the noise and increase the speed, but it would be very ineffective if there were high potential differences between the input and output.

Solid-State Relay

Through the use of transistor circuits, mechanical relays are slowly being replaced by solid-state relays. In some cases, the solid-state relay (SSR) offers distinct advantages over its mechanical counterpart. For example, an SSR has the advantage that it has neither moving parts nor fragile wires and it has faster switching speeds and longer operating life. However, one disadvantage of an SSR is that it generally has a lower degree of input/output isolation than a mechanical relay. To overcome this disadvantage in the SSR, an opto-coupler can be used as the isolating input stage as shown in the block diagram in Figure 11. The control stage may consist of discrete transistors or integrated circuits, while the output stage consists of high-power switching devices.

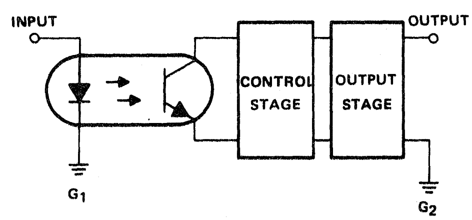

FIGURE 11. Typical Solid-State Relay Using an Opto-Coupler

A simple isolated latch circuit, which is somewhat of an SSR, is shown in Figure 12. The output of the opto-coupler is used to fire the SCR that provides power to the load. To turn off the load current, the supply voltage V_{CC2} must be removed.

Isolated Chopper Circuit

Chopper circuits that use mechanical relays suffer from a speed problem as well as switching transients at the

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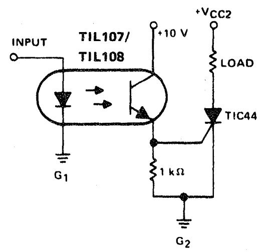

FIGURE 12. Solid-State Latch Using a TIL107/TIL108

load. By using bipolar transistors or FETs as series and shunt switching elements, the speed may be improved; but capacitive coupling to the switching circuitry may still produce transient "spikes" on the output signal. By using an opto-coupler to switch the input signal as shown in Figure 13, the switching circuitry can be isolated from the output, thereby reducing output "spikes". The use of two couplers in the configuration shown allows chopping of either positive or negative input signals with a frequency of one-half that of the input to the flip-flop. The SN72741 operational amplifier is used to increase the output signal with a gain of R_2/R_1.

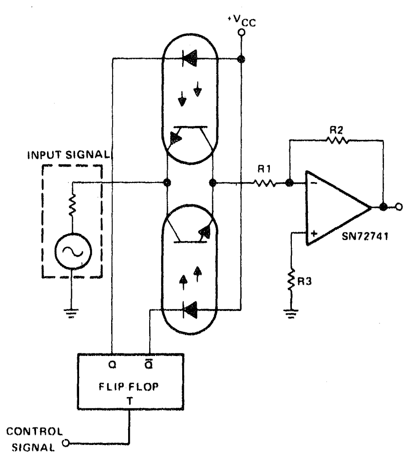

FIGURE 13. Chopper Circuit Using Opto-Couplers

Pulse Amplifiers

Pulse amplification, as well as isolation, can be achieved by using an opto-coupler with a pulse amplifier. The circuit shown in Figure 14 uses an isolator with an SN72741 operational amplifier to amplify the pulse appearing at the anode of the IRED. The gain of this circuit is

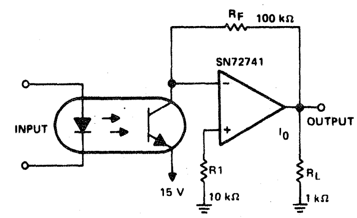

FIGURE 14. Isolated Pulse Amplifier Using Opto-Coupler and SN72741 Operational Amplifier

controlled by the feedback resistor R_F. An amplifier employing discrete components and that uses the TIL102/TIL103 as part of the current feedback pair is shown in Figure 15. The feedback resistor R_1 controls the current gain as well as the output d-c level.

Figure 16 shows an opto-coupler with a voltage-feedback amplifier that has a gain of $1 + R_2/R_1$. This type of amplifier offers high input impedance, which will not load the emitter of the sensor transistor.

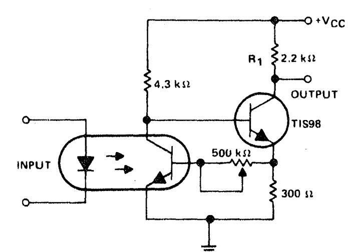

FIGURE 15. Discrete-Component Pulse Amplifier with TIL102/TIL103

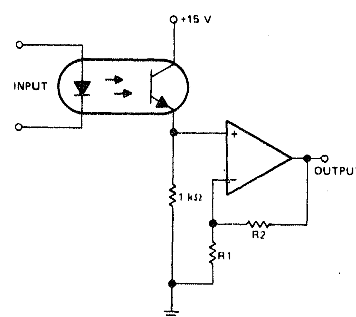

FIGURE 16. Voltage-Feedback Pulse Amplifier with Opto-Coupler

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OPTO-COUPLERS

The opto-coupler is designed as the solid-state replacement for mechanical relays and pulse transformers. Functionally, the opto-coupler is similar to its older mechanical counterpart because it offers a high degree of isolation between a pair of input and output terminals. However, unlike the older mechanical devices that transfer signals by magnetic coupling, opto-couplers transfer signals by a photon-coupling process. Briefly, opto-couplers are the logical choice over mechanical relays and pulse transformers because they offer:

For relay functions:

- Faster operating speeds
- Positive (no bounce) action
- Insensitiveness to vibration and shock
- Long life as there are no moving contacts to wear or pit
- Wide operating temperature range as there are no moving contacts to stick
- Small size
- Compatibility with DTL and TTL integrated circuits

For transformer functions:

- Frequency response from dc to 100 kHz
- Lower coupling capacitance for better common-mode rejection
- Small size
- Improved shock and vibration resistance

OPTO-COUPLER CONFIGURATION

The input stage of an opto-coupler consists of a highly efficient GaAs (gallium arsenide) infrared-emitting diode. When forward biased at a relatively low current level, the infrared-emitting diode emits photons that have an optical wavelength in the near-infrared region of about 0.9 μm.

The output stage of an opto-coupler consists of a Si (silicon) phototransistor. This radiation-sensitive device responds most efficiently to optical wavelengths in the 0.9-μm region. Hence, the photon-coupled input and output stages are spectrally matched for optimum input-to-output transfer ratio.

Several types of opto-couplers are presently offered by Texas Instruments as standard products. These devices differ primarily in the types of emitters and phototransistors used and in the method used to obtain electrical isolation. Figure 1 shows the outline drawings for both the TIL102/TIL103 and the TIL107/TIL108 opto-couplers. Note that both series of devices consist of the input-stage emitter and the output-stage phototransistor. However, the TIL102/TIL103 is constructed with a thin layer of infrared-transmitting glass between the input and output stages while the TIL107/TIL108 uses an air gap to attain higher electrical isolation.

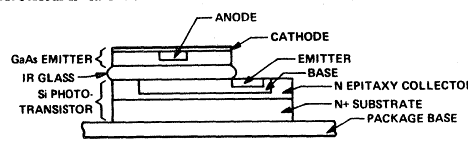

FIGURE 1a. Details of TIL102/TIL103 Construction

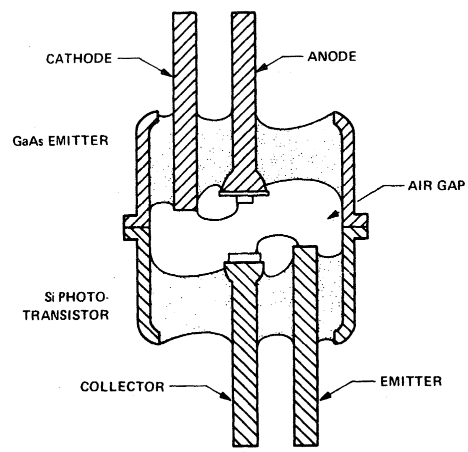

FIGURE 1b. Details of TIL107/TIL108 Construction

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Regardless of whether an air gap or IR-transmitting glass is used to separate the input and output terminals, the operating characteristics are basically the same. When an input signal (forward bias current) is applied to the infrared-emitting diode, photons are absorbed in the phototransistor, thus providing conduction between the output terminal leads. Figure 2 indicates schematically how the input and output stages of the TIL102/TIL103 and TIL107/TIL108 are arranged.

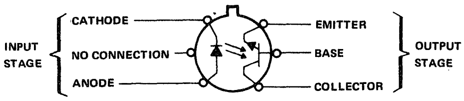


FIGURE 2a. TIL102/TIL103 Input and Output Terminal Connections

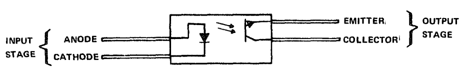


FIGURE 2b. TIL107/TIL108 Input and Output Terminal Connections

UNIQUE ADVANTAGES OF THE OPTO-COUPLER

Aside from the fact that opto-couplers are of solid-state construction and possess no moving contacts, which would eventually freeze or wear out, they offer several other unique advantages.

Small Size

As shown in Figure 3, the TIL102/TIL103 devices are packaged in modified TO-78 cases, which allows the user to mount devices in medium-density applications. The TIL107/TIL108 devices are enclosed in a doubled-flanged package with a diameter similar to that of a standard TO-18 device. Close-proximity mounting into printed circuit boards is attainable, and both packages are hermetically sealed to allow operation under extreme environmental conditions.

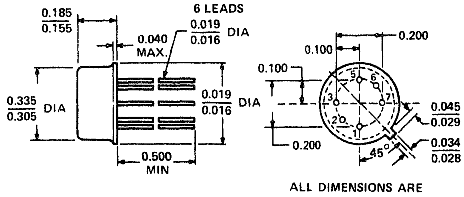


FIGURE 3a. Mechanical Data of TIL102/TIL103

High-Voltage Electrical Isolation

The voltage-isolation characteristic of opto-couplers allows the user to transmit signals between two or more terminals within a system when large voltage potential differences exist. The TIL102/TIL103 series and TIL107/TIL108 series are capable of isolating up to 1000 volts. Since physical packaging usually limits voltage isolation capabilities, the package can be modified to attain several thousand volts isolation with multimegohm leakage resistance and picofarad coupling-capacitance.

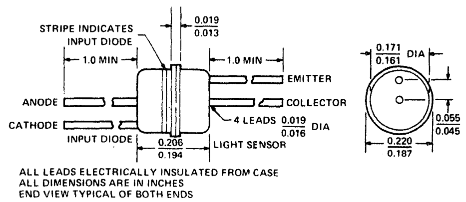


FIGURE 3b. Mechanical Data of TIL107/TIL108

High Gain

As outlined in Table I, the TIL102 and TIL103 have typical input-to-output current ratios of 0.6 and 1.5, respectively. Since the TIL103 has a gain factor greater than 1, the need for amplifiers behind the opto-coupler output stage is eliminated. While the TIL107/TIL108 devices have typical current gain ratios of approximately 0.1 and 0.2, respectively, both are designed to operate with input and output currents that are compatible with standard DTL and TTL integrated circuits. Figure 4 outlines typical output currents for various input current levels.

High Speed

Table II outlines the typical switching characteristics for the TIL102/TIL103 and TIL107/TIL108 series of opto-couplers at 25°C case temperature. Note that the rise, fall, delay, and storage times for these solid-state opto-couplers are measured in *micro*seconds. Thus, they are typically 1000 times faster than conventional mechanical relays, which have switching speeds in the *milli*second range.

Wide Operating – Temperature Range

The GaAs input diode and the Si phototransistor have temperature coefficients that offset each other. An increase in temperature will cause the GaAs emitter to emit fewer photons while the phototransistor will increase in sensitivity. On the other hand, at low temperatures the efficiency of the GaAs emitter increases and more photons are emitted, but the phototransistor sensitivity decreases.

For this reason, the overall current gain of the opto-coupler is fairly stable over a wide temperature range. Figure 5a shows typical relative output of the TIL102/TIL103 series while Figure 5b shows the typical relative output current for the TIL107/TIL108 series. Note that both sets of characteristic curves show input versus output currents over a –55°C to 125°C temperature range. This operating-range stability offers the user a wide degree of flexibility for applications which involve MIL-Spec temperatures.

Opto-couplers are also valuable for coupling either analog or digital signals between terminals in a system. Since ground looping problems are avoided when opto-couplers are used, spurious noise from circulating ground currents is eliminated. In addition, the d-c isolation characteristic of opto-couplers will allow signal transfer, despite the fact that large voltage potential differences may exist between the various terminals of a system.

Table I

DEVICE	TEST CONDITIONS	INPUT CURRENT	TYPICAL OUTPUT CURRENT
TIL102	V_{CE} = 5 V, I_B = 0	I_F = 10 mA	6 mA
TIL103	V_{CE} = 5 V, I_B = 0	I_F = 10 mA	15 mA
TIL107	V_{CE} = 5 V	I_F = 15 mA I_F = 35 mA	1 mA 4 mA
TIL108	V_{CE} = 5 V	I_F = 15 mA I_F = 35 mA	2 mA 7 mA

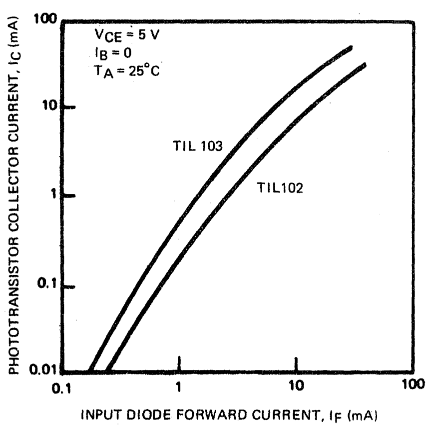


FIGURE 4a. Input Current versus Output Current for TIL102/TIL103

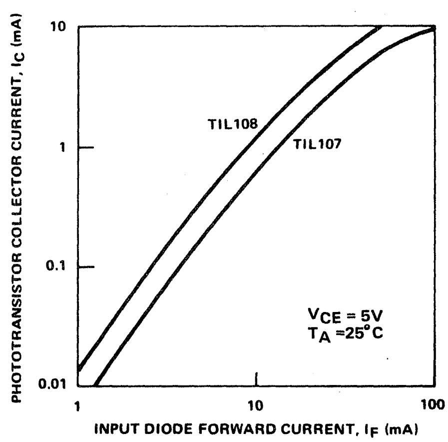


FIGURE 4b. Input Current versus Output Current for TIL107/TIL108

Table II

DEVICE	TEST CONDITIONS	TYPICAL DELAY TIME	TYPICAL RISE TIME	TYPICAL STORAGE TIME	TYPICAL FALL TIME
TIL102	V_{CC} = 20 V, $I_{C(on)}$ =	0.5 μs	3 μs	0.1 μs	3 μs
TIL103	5 mA, R_L = 100 Ω	0.5 μs	6 μs	0.2 μs	6 μs
TIL107	V_{CC} = 35 V, $I_{C(on)}$ =	3 μs	5 μs	0.5 μs	5 μs
TIL108	500 μA, R_L = 1 kΩ	3 μs	5 μs	0.5 μs	5 μs

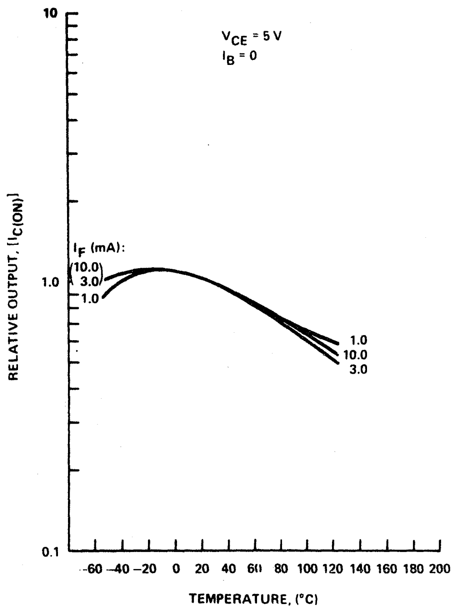


FIGURE 5a. Relative Output Current versus Temperature for TIL102/TIL103

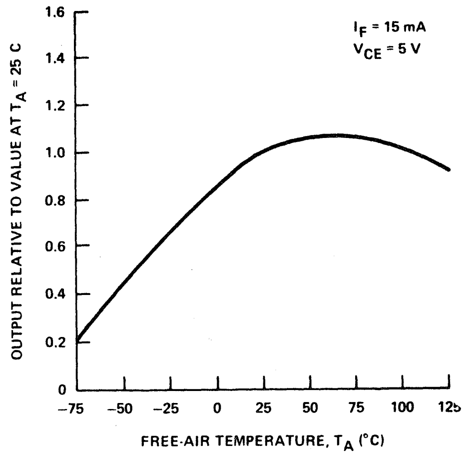


FIGURE 5b. Relative Output Current versus Temperature for TIL107/TIL108

Sensor/Emitter Arrays

6

SENSOR-EMITTER ARRAYS
QUICK REFERENCE GUIDE

DEVICE	TYPE	POWER OUTPUT MIN @ I_F = 50 mA	V_F MAX @ I_F = 50 mA	I_L MIN @ V_{CE} = 5 V	I_C @ I_F = 50 mA V_{CE} = 5 V	$V_{CE(sat)}$ TYP @ I_C = 2 mA I_F = 50 mA	FEATURES
TIL131	Nine-element gallium arsenide IRED array	0.4 mW	1.5 V				Nine TIL23's mounted on 0.1-inch centers. For paper tape readers.
TIL132	Nine-element photo-transistor array			2 mA			Nine LS600's mounted on 0.1-inch centers in double-sided p-c board
TIL133	Nine-channel IRED-phototransistor pair				2.5 mA to 10 mA	0.4 V	Consists of a TIL131 and a TIL132 with guaranteed channel performance
TIL134	Twelve-element gallium arsenide IRED array	0.4 mW	1.5 V				Twelve TIL23's mounted on 0.250-inch centers. For reading punched cards.
TIL135	Twelve-element photo-transistor array			2 mA			Twelve LS600's mounted on 0.250-inch centers in double-sided p-c board
TIL136	Twelve-channel IRED-phototransistor pair				2.5 mA to 10 mA	0.4 V	Consists of a TIL134 and TIL135 with guaranteed channel performance

DEVICE	TYPE	ON-STATE COLLECTOR CURRENT MIN $I_{C(on)}$	@ I_F	@ V_{CE}	OFF-STATE COLLECTOR CURRENT MAX $I_{C(off)}$	@ V_{CE}	FEATURES
TIL138	One-channel trans-missive assembly	1.6 mA 0.4 mA	35 mA 15 mA	0.5 V 0.5 V	25 nA	30 V	A TIL32 gallium arsenide IRED and a TIL78 phototransistor mounted in a plastic housing
TIL139	One-channel reflective assembly	10 µA†	40 mA	5 V	25 nA	30 V	A TIL32 and a TIL78 mounted in a plastic housing
TIL143	One-channel trans-	200 µA	20 mA	10 V	100 nA	10 V	Standard dual-in-line pin spacing
TIL144	missive assembly	50 µA	20 mA	10 V	100 nA	10 V	
TIL145	One-channel trans-	2 mA	16 mA	1 V	100 nA	5 V	High-gain darlington phototransistor.
TIL146	missive assembly	1.6 mA	50 mA	1 V	100 nA	5 V	Standard dual-in-line pin spacing
TIL147	One-channel trans-	4 mA	20 mA	5 V	100 nA	10 V	Standard dual-in-line pin spacing
TIL148	missive assembly	1 mA	20 mA	5 V	100 nA	10 V	
TIL149	One-channel reflective assembly	100 µA‡	40 mA	5 V	100 nA	15 V	A TIL32 and a phototransistor similar to TIL78 in a plastic housing.

†Reflective surface is Eastman Kodak (or equivalent) neutral white paper with 90% diffuse reflectance placed 0.150 inch from read head.
‡Refelctive surface is 0.001-inch thick aluminum foil, typical of beginning-of-tape/end-of-tape strips on magnetic tape surface, placed 0.150 inch from read head.

DEVICE	TYPE	V_{OH} MIN	V_{OL} MAX	I_{CC} MAX	FEATURES
TIL141	12-channel integrated	2.4 V	0.4 V	410 mA	TTL/DTL-compatible output levels. TIL142 has plug-in
TIL142	optical reader	2.4 V	0.4 V	410 mA	connector

For other arrays, see the following sections in this book: *Photodetectors, Infrared Emitters, and Light-Emitting Diodes.*

BULLETIN NO. DL-S 7111554, SEPTEMBER 1971

TIL131 . . . 9-ELEMENT GALLIUM ARSENIDE IRED ARRAY
TIL132 . . . 9-ELEMENT PHOTOTRANSISTOR ARRAY
TIL133 . . . 9-CHANNEL PAIR

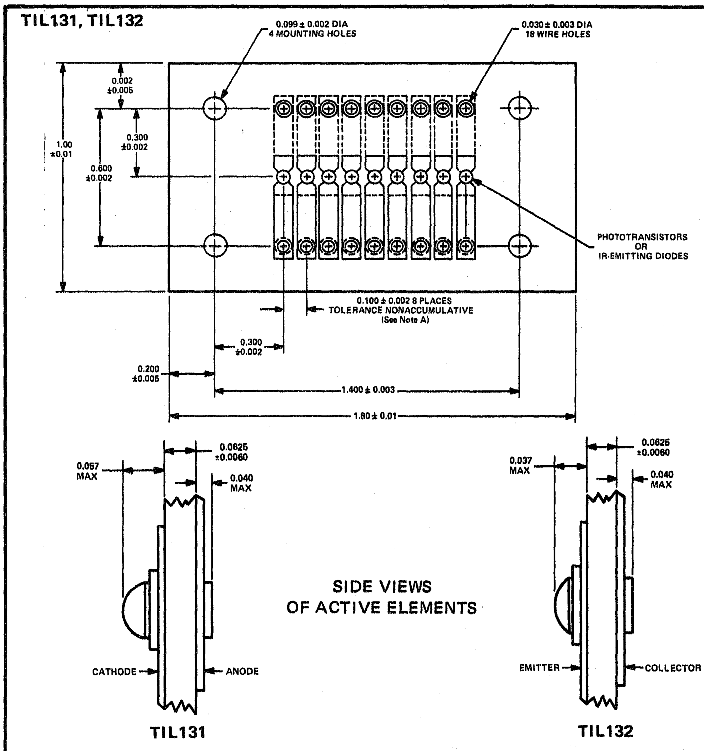
- **Center-to-Center Spacing of 0.100 Inch for Tape Reading**
- **Reliable Solid-State Components**
- **IRED's Eliminate Lamp-Filament-Sag Problems**
- **Spectrally Matched for Improved Performance**
- **Printed Circuit Board Construction Allows Precise Alignment**

description

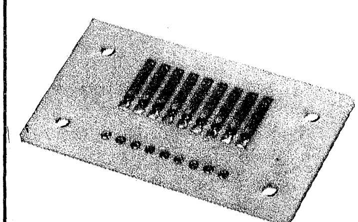
The TIL131 is an array of nine TIL23 gallium arsenide infrared-emitting diodes mounted in a printed circuit board. The TIL132 is an array of nine selected LS600 phototransistors. The TIL133 is a pair of selected arrays comprising a TIL131 and TIL132 and offering guaranteed channel performance.

mechanical data

The printed circuit board material is glass-base FR-4, class II, 2-oz copper clad on both sides. The approximate weight of the TIL131 and TIL132 is 3.7 grams each.



NOTE A: Tolerances shown on drawing apply for location dimensions of the mounting holes and the active elements. Tolerance of ±0.005 applies for location dimensions of wire holes.



6

TIL131 absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Reverse Voltage . . . . 2 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1) . . . . . . 100 mA
Operating Free-Air Temperature Range . . . . −65°C to 125°C
Storage Temperature Range . . . . −65°C to 150°C
Soldering Temperature (10 Seconds) . . . . 240°C

NOTE 1: Derate linearly to 125°C free-air temperature at the rate of 1 mA/°C.

TIL131 operating characteristics of each element at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 50 mA	0.4		1	mW
λ_p	Wavelength at Peak Emission			0.93		μm
$\Delta\lambda$	Spectral Bandwidth			500		Å
θ_{HI}	Half-Intensity Beam Angle			35°		
V_F	Static Forward Voltage			1.25	1.5	V

6

TIL132 absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Emitter Voltage . . . . 50 V
Emitter-Collector Voltage . . . . 7 V
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2) . . . . . . 50 mW
Operating Free-Air Temperature Range . . . . −65°C to 125°C
Storage Temperature Range . . . . −65°C to 150°C
Soldering Temperature (10 Seconds) . . . . 240°C

NOTE 2: Derate linearly to 125°C free-air temperature at the rate of 0.5 mW/°C.

TIL132 electrical characteristics at 25°C free-air temperature

individual element characteristics

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 100 μA,	E_e = 0	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	I_E = 100 μA,	E_e = 0	7			V
I_D	Dark Current	V_{CE} = 30 V,	E_e = 0			100	nA
I_L	Light Current	V_{CE} = 5 V,	E_e = 20 mW/cm², See Note 3	2		12	mA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 0.4 mA,	E_e = 20 mW/cm², See Note 3		0.15		V

element matching characteristics

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$\frac{I_{L min}}{I_{L max}}$	Light Current Matching Factor	V_{CE} = 5 V,	E_e = 20 mW/cm², See Note 3	0.5			

NOTE 3: Irradiance (E_e) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

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TIL133 absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Maximum ratings of TIL131 and TIL132 apply.

TIL133 electrical characteristics at 25°C free-air temperature

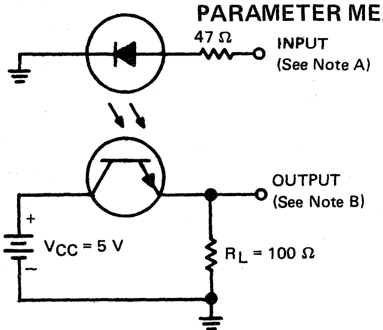
PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
I_C	Output Collector Current	I_F = 50 mA, V_{CE} = 5 V	2.5	4	10	mA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_F = 50 mA, I_C = 2 mA		0.4	0.7	V

TIL133 switching characteristics at 25°C free-air temperature

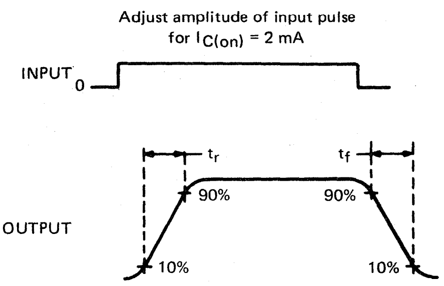
PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
t_r	Rise Time	V_{CC} = 5 V, $I_{C(on)}$ = 2 mA,		1.5		μs
t_f	Fall Time	R_L = 100 Ω, See Figure 1		1.5		μs

†These parameters are measured at a lens-to-lens distance of 0.100 inch.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGES WAVEFORMS

NOTES: A. The input waveform is supplied by a generator with the following characteristics: Z_{out} = 50 Ω, t_r ≤ 15 ns, duty cycle ≈ 1%, t_w = 100 μs.

B. The output waveform is monitored on an oscilloscope with the following characteristics: t_r ≤ 12 ns, R_{in} ≥ 1 MΩ, C_{in} ≤ 20 pF.

FIGURE 1—SWITCHING TIMES

TYPICAL CHARACTERISTICS

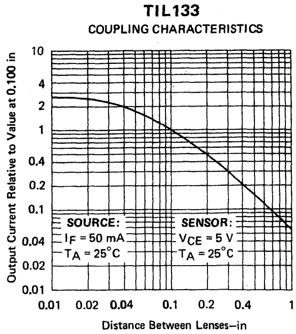


FIGURE 2

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TYPICAL CHARACTERISTICS

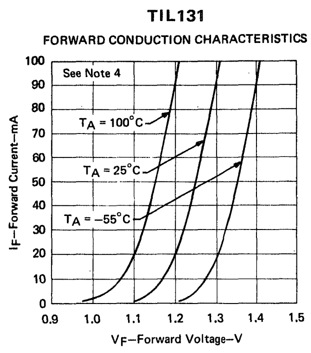

FIGURE 3

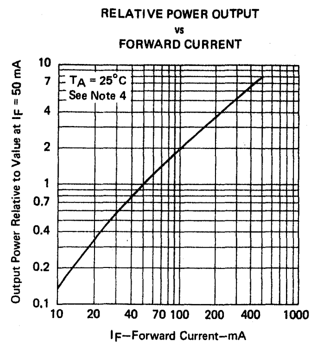

FIGURE 4

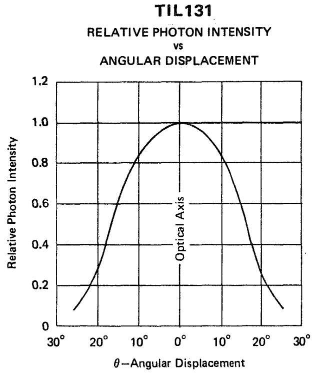

FIGURE 5

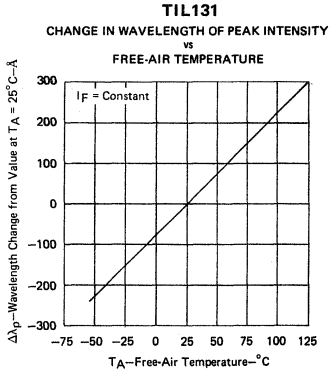

FIGURE 6

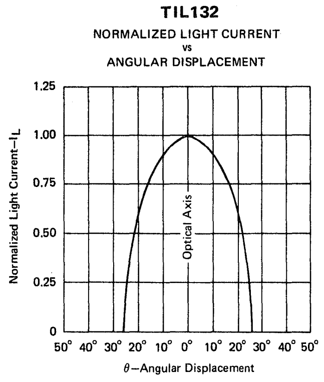

FIGURE 7

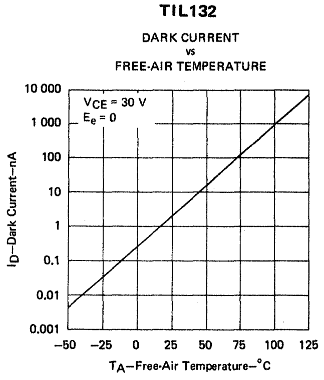

FIGURE 8

NOTE 4: These parameters were measured using pulse techniques $t_w = 0.04$ ms, duty cycle $\leq 10\%$.

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PRINTED IN U.S.A. 1174

BULLETIN NO. DL-S 7111561, SEPTEMBER 1971

TIL134 . . . 12-ELEMENT GALLIUM ARSENIDE IRED ARRAY
TIL135 . . . 12-ELEMENT PHOTOTRANSISTOR ARRAY
TIL136 . . . 12-CHANNEL PAIR

- **Center-to-Center Spacing of 0.250 Inch for Tape Reading**
- **Reliable Solid-State Components**
- **IRED's Eliminate Lamp-Filament-Sag Problems**
- **Spectrally Matched for Improved Performance**
- **Printed Circuit Board Construction Allows Precise Alignment**

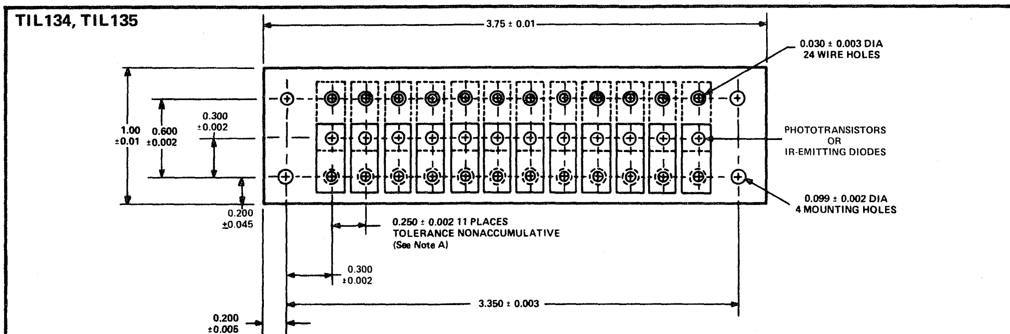
description

The TIL134 is an array of twelve TIL23 gallium arsenide infrared-emitting diodes mounted in a printed circuit board. The TIL135 is an array of twelve selected LS600 phototransistors. The TIL136 is a pair of selected arrays comprising a TIL134 and TIL135 and offering guaranteed channel performance.

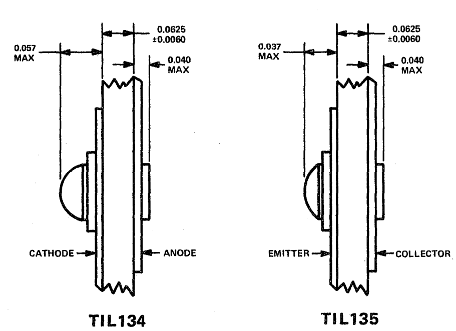
mechanical data

The printed circuit board material is glass-base FR-4, class II, 2-oz copper clad on both sides. The approximate weight of the TIL134 and TIL135 is 8.5 grams each.

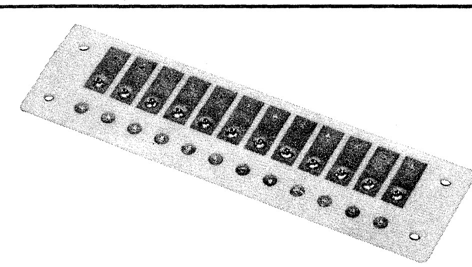
TIL134, TIL135



NOTE A: Tolerances shown on drawing apply for location dimensions of the mounting holes and the active elements. Tolerance of ±0.005 applies for location dimensions of wire holes.



SIDE VIEWS OF ACTIVE ELEMENTS



3/4 ACTUAL SIZE

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TIL134 absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Reverse Voltage . . . . 2 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1) . . . . . . 100 mA
Operating Free-Air Temperature Range . . . . −65°C to 125°C
Storage Temperature Range . . . . −65°C to 150°C
Soldering Temperature (10 Seconds) . . . . 240°C

NOTE 1: Derate linearly to 125°C free-air temperature at the rate of 1 mA/°C.

TIL134 operating characteristics of each element at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 50 mA	0.4		1	mW
λ_p	Wavelength at Peak Emission			0.93		μm
$\Delta\lambda$	Spectral Bandwidth			500		Å
θ_{HI}	Half-Intensity Beam Angle			35°		
V_F	Static Forward Voltage			1.25	1.5	V

6

TIL135 absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Collector-Emitter Voltage . . . . 50 V
Emitter-Collector Voltage . . . . 7 V
Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2) . . . . . . 50 mW
Operating Free-Air Temperature Range . . . . −65°C to 125°C
Storage Temperature Range . . . . −65°C to 150°C
Soldering Temperature (10 Seconds) . . . . 240°C

NOTE 2: Derate linearly to 125°C free-air temperature at the rate of 0.5 mW/°C.

TIL135 electrical characteristics at 25°C free-air temperature

individual element characteristics

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 100 μA,	E_e = 0	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	I_E = 100 μA,	E_e = 0	7			V
I_D	Dark Current	V_{CE} = 30 V,	E_e = 0			100	nA
I_L	Light Current	V_{CE} = 5 V,	E_e = 20 mW/cm^2, See Note 3	2		12	mA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 0.4 mA,	E_e = 20 mW/cm^2, See Note 3		0.15		V

element matching characteristics

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$\frac{I_{L min}}{I_{L max}}$	Light Current Matching Factor	V_{CE} = 5 V,	E_e = 20 mW/cm^2, See Note 3	0.5			

NOTE 3: Irradiance (E_e) is the radiant power per unit area incident upon a surface. For this measurement the source is an unfiltered tungsten linear-filament lamp operating at a color temperature of 2870 K.

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TIL136 absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Maximum ratings of TIL134 and TIL135 apply.

TIL136 electrical characteristics at 25°C free-air temperature

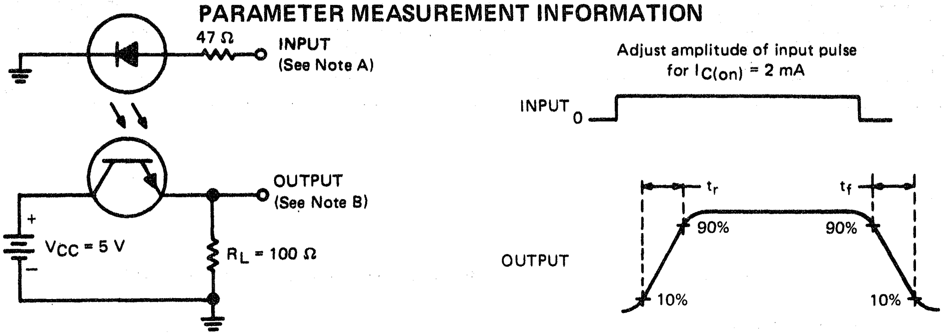
PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
I_C	Output Collector Current	$I_F = 50$ mA, $V_{CE} = 5$ V	2.5	4	10	mA
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_F = 50$ mA, $I_C = 2$ mA		0.4	0.7	V

TIL136 switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
t_r	Rise Time	$V_{CC} = 5$ V, $I_{C(on)} = 2$ mA,		1.5		μs
t_f	Fall Time	$R_L = 100\ \Omega$, See Figure 1		1.5		μs

†These parameters are measured at a lens-to-lens distance of 0.100 inch.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGES WAVEFORMS

NOTES: A. The input waveform is supplied by a generator with the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 15$ ns, duty cycle ≈ 1%, $t_w = 100$ μs.
B. The output waveform is monitored on an oscilloscope with the following characteristics: $t_r \leq 12$ ns, $R_{in} \geq 1$ MΩ, $C_{in} \leq 20$ pF.

FIGURE 1–SWITCHING TIMES

TYPICAL CHARACTERISTICS

TIL136
COUPLING CHARACTERISTICS

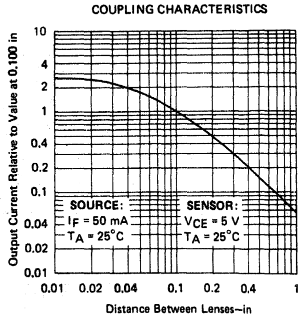


FIGURE 2

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6

TYPICAL CHARACTERISTICS

TIL134
FORWARD CONDUCTION CHARACTERISTICS

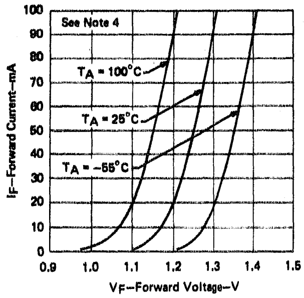

FIGURE 3

TIL134
RELATIVE POWER OUTPUT
vs
FORWARD CURRENT

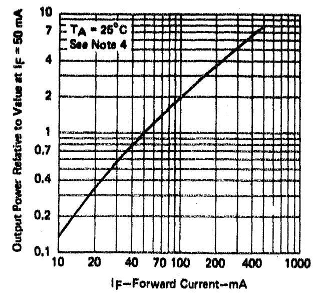

FIGURE 4

TIL134
RELATIVE PHOTON INTENSITY
vs
ANGULAR DISPLACEMENT

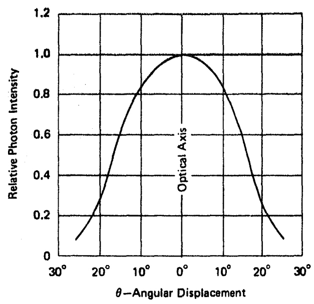

FIGURE 5

TIL134
CHANGE IN WAVELENGTH OF PEAK INTENSITY
vs
FREE-AIR TEMPERATURE

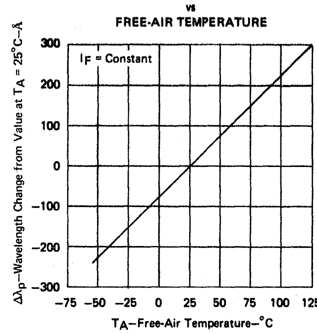

FIGURE 6

TIL135
NORMALIZED LIGHT CURRENT
vs
ANGULAR DISPLACEMENT

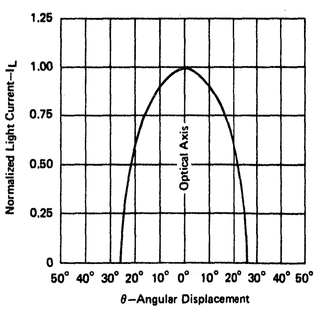

FIGURE 7

TIL135
DARK CURRENT
vs
FREE-AIR TEMPERATURE

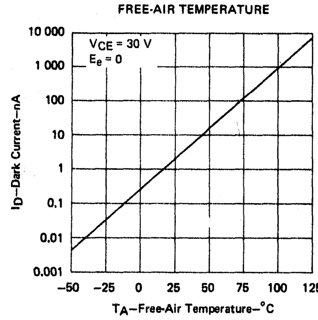

FIGURE 8

NOTE 4: These parameters were measured using pulse techniques t_w = 0.04 ms, duty cycle ≤ 10%.

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PRINTED IN U.S.A. 1174

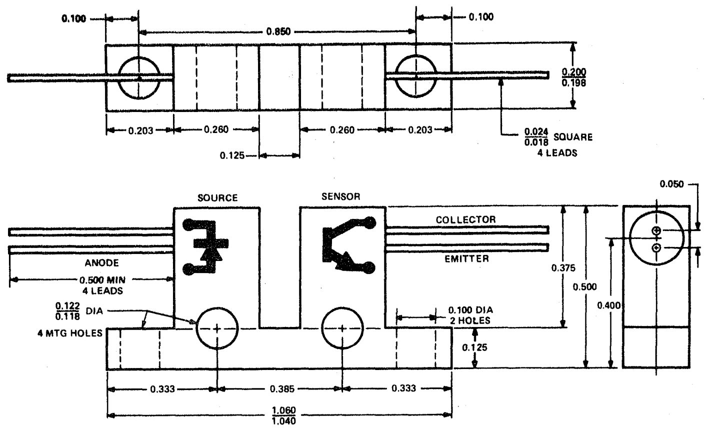
BULLETIN NO. DL-S 7611558, SEPTEMBER 1971–REVISED MARCH 1976

OPTOELECTRONIC MODULE FOR TRANSMISSIVE SENSING APPLICATIONS

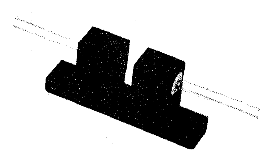
- **Compatible With Standard DTL and TTL Integrated Circuits**
- **High-Speed Switching: t_r = 1.5 μs, t_f = 15 μs Typical**
- **Designed for Base or Side Mounting**
- **For Sensing Applications such as Shaft Encoders, Sector Sensors, Level Indicators, and Beginning-of-Tape/End-of-Tape Indicators**

mechanical data

The assembly consists of a TIL32 gallium arsenide infrared-emitting diode and a TIL78 n-p-n silicon phototransistor mounted in a molded ABS† plastic housing. The assembly will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Total assembly weight is approximately 1.5 grams.



ALL DIMENSIONS ARE IN INCHES WITH TOLERANCE OF ±0.005 UNLESS OTHERWISE NOTED.



absolute maximum ratings at 25 °C free-air temperature (unless otherwise noted)

Source Reverse Voltage	2 V
Source Continuous Forward Current (See Note 1)	40 mA
Sensor Collector-Emitter Voltage	50 V
Sensor Emitter-Collector Voltage	7 V
Sensor Continuous Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	50 mW
Storage Temperature Range	−40°C to 85°C
Lead Temperature 1/16 Inch from Assembly for 5 Seconds	240°C

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.73 mA/°C.
2. Derate linearly to 80°C free-air temperature at the rate of 0.91 mW/°C.

†ABS thermoplastics are derived from acrylonitrile, butadiene and styrene.

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TYPE TIL138
SOURCE AND SENSOR ASSEMBLY

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$, $I_F = 0$	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 100\ \mu A$, $I_F = 0$	7			V
$I_{C(off)}$	Off-State Collector Current	$V_{CE} = 30\ V$, $I_F = 0$			25	nA
$I_{C(on)}$	On-State Collector Current	$V_{CE} = 0.5\ V$, $I_F = 15\ mA$	0.4	1		mA
		$V_{CE} = 0.5\ V$, $I_F = 35\ mA$	1.6	4		
V_F	Input-Diode Static Forward Voltage	$I_F = 15\ mA$		1.15	1.5	V
		$I_F = 35\ mA$		1.2		

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
t_d	Delay Time	$V_{CC} = 30\ V$, $I_{C(on)} = 500\ \mu A$, $R_L = 1\ k\Omega$, See Figure 1		3		μs
t_r	Rise Time			1.5		μs
t_s	Storage Time			0.5		μs
t_f	Fall Time			15		μs

†Stray irradiation outside the range of device sensitivity may be present. A satisfactory condition has been achieved when the parameter being measured approaches a value which cannot be altered by further irradiation shielding.

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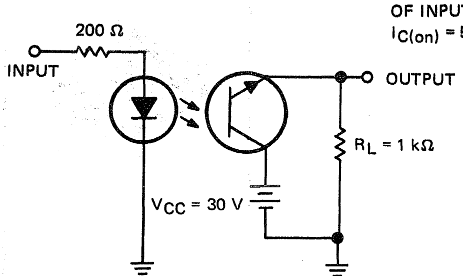
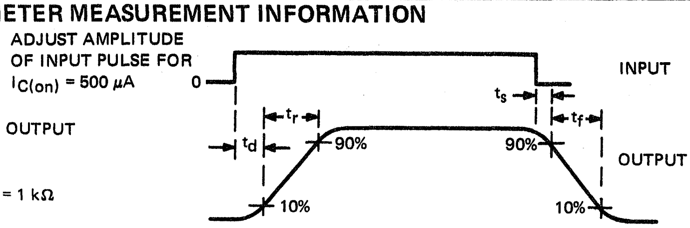
PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



NOTE: The input pulse is supplied by a generator having the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 100$ ns, $t_f \leq 100$ ns, duty cycle ≈ 50%.

VOLTAGE WAVEFORMS

FIGURE 1—SWITCHING TIMES

TYPICAL CHARACTERISTICS

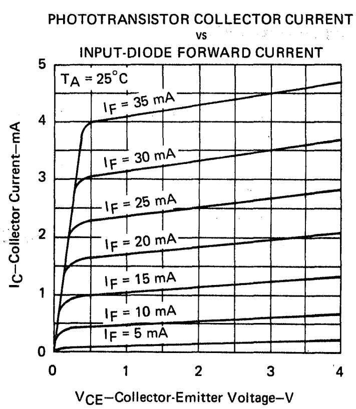


FIGURE 2

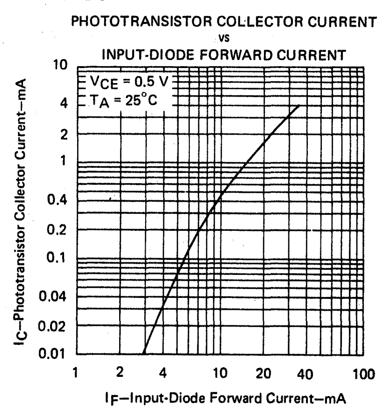


FIGURE 3

PRINTED IN U.S.A. 971

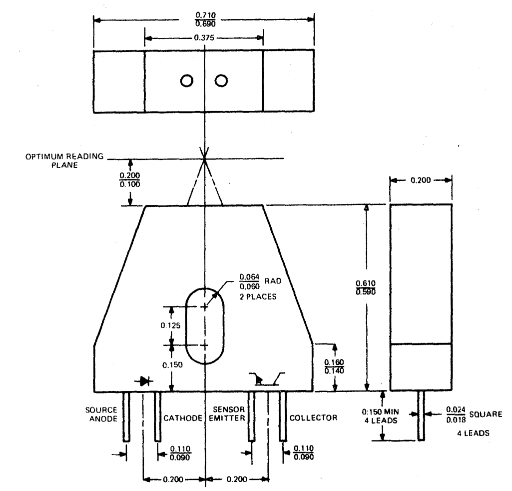
BULLETIN NO. DL-S 7611559, SEPTEMBER 1971—REVISED MARCH 1976

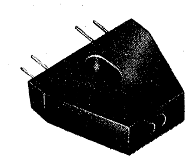
OPTOELECTRONIC MODULE FOR REFLECTIVE SENSING APPLICATIONS

- **Adaptable for Printed Circuit Board Mounting**
- **Designed for Sensing Applications such as Line Finders, Batch Counters, Level Indicators, and Beginning-of-Tape/End-of-Tape Indicators**

mechanical data

The assembly consists of a TIL32 gallium arsenide infrared-emitting diode and a TIL78 n-p-n silicon phototransistor mounted in a molded ABS† plastic housing. The assembly will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Total assembly weight is approximately 1.2 grams.





All dimensions are in inches with tolerance of ±0.005 unless otherwise noted.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Source Reverse Voltage	2 V
Source Continuous Forward Current (See Note 1)	40 mA
Sensor Collector-Emitter Voltage	50 V
Sensor Emitter-Collector Voltage	7 V
Sensor Continuous Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	50 mW
Storage Temperature Range	−40°C to 85°C
Lead Temperature 1/16 Inch from Assembly for 5 Seconds	240°C

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.73 mA/°C.
2. Derate linearly to 80°C free-air temperature at the rate of 0.91 mW/°C.

†ABS thermoplastics are derived from acrylonitrile, butadiene, and styrene.

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 100 µA, I_F = 0	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	I_E = 100 µA, I_F = 0	7			V
$I_{C(off)}$	Off-State Collector Current	V_{CE} = 30 V, I_F = 0			25	nA
$I_{C(on)}$	On-State Collector Current	V_{CE} = 5 V, I_F = 40 mA, See Note 3	10	125		µA
		V_{CE} = 5 V, I_F = 40 mA, See Note 4	5	60		
		V_{CE} = 5 V, I_F = 40 mA, See Note 5	100	1100		
V_F	Input-Diode Static Forward Voltage	I_F = 40 mA		1.2	1.6	V

†Stray irradiation outside the range of device sensitivity may be present. A satisfactory condition has been achieved when the parameter being measured approaches a value which cannot be altered by further irradiation shielding.

NOTES: 3. Reflective surface is Eastman Kodak (or equivalent) neutral white paper with 90% diffuse reflectance placed 0.150 inch from read head.
4. Reflective surface is Mylar‡ (or equivalent) magnetic tape placed 0.150 inch from read head.
5. Reflective surface is 0.001-inch-thick aluminum foil, typical of beginning-of-tape/end-of-tape strips on magnetic tape surface, placed 0.150 inch from read head.

‡Trademark of E. I. duPont

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TEXAS INSTRUMENTS
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BULLETIN NO. DL-S 7412381, NOVEMBER 1974

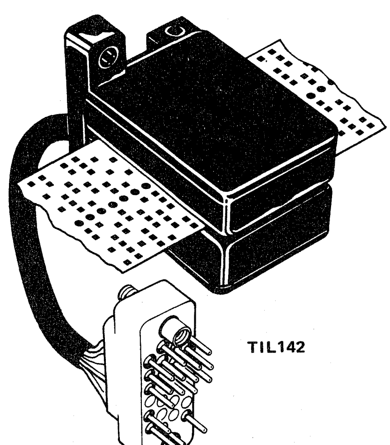
- **Center-to-Center Channel Spacing of 0.109 Inch, Except 0.250 Inch Between Channels 6 and 7, to be Compatible with Paper Tape Vertical-Format Unit Requirements For Line Printers**
- **Spectrally Matched, Hermetically Sealed Sensors and Emitters Similar to TIL604 and TIL23 with a Proven Reliability History**
- **Proprietary Design† Eliminates Aperture Holes in the Plastic Housing Preventing Dust Problems**
- **TTL Compatible Output—Fan-Out to 10 Standard Series 54/74 Loads**
- **Design Goal of 100,000 Hours Operation through Component Selection and Production Testing of Internal Nodes**
- **Printed-Board Construction Allows Precise Alignment of Emitters and Sensors**

6

description

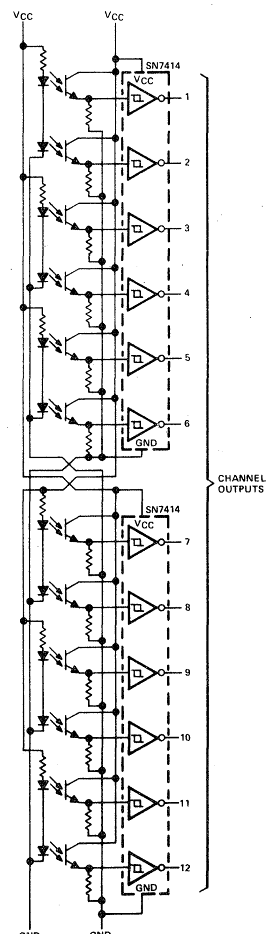
The TIL141 and TIL142 are 12-channel integrated optical readers for paper tape such as Burroughs 10020717, IBM 429754, or the equivalent. Each consists of 12 TIL23 infrared-emitting diodes (IRED's), 12 TIL604 phototransistors, two SN7414 hex Schmitt-trigger inverters, and the appropriate load resistors. Metal-film resistors are used to ensure maximum stability. The TIL141 has seven-inch-long wire leads for soldering directly into the circuit. The TIL142 has a plug-in connector.

Each infrared-emitting diode transmits through the open-air gap of the tape slot to a phototransistor that drives one of the Schmitt-trigger inverters. An obstruction (transmissivity ≤15%) in the gap between an IRED and its phototransistor will cause a high output while a clear gap will cause a low output. Data holes in the tape should have a minimum width of 0.060 inch.



TIL142

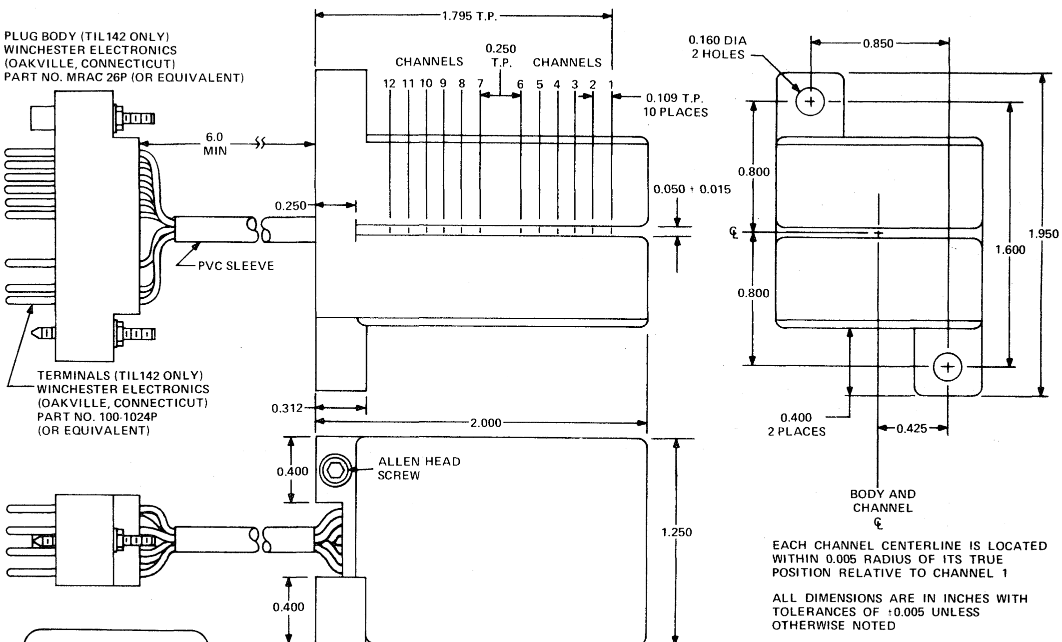
functional diagram



† Patent pending

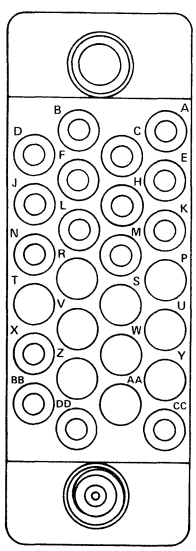
mechanical data

The plastic housing is soluble in chlorinated hydrocarbons and ketones. Methanol or isopropanol are recommended as cleaning agents. Device performance characteristics remain stable when operated under high-humidity conditions.



EACH CHANNEL CENTERLINE IS LOCATED WITHIN 0.005 RADIUS OF ITS TRUE POSITION RELATIVE TO CHANNEL 1

ALL DIMENSIONS ARE IN INCHES WITH TOLERANCES OF ±0.005 UNLESS OTHERWISE NOTED



VIEW IS FROM PIN SIDE OF PLUG

FUNCTION	WIRE COLOR CODE	TIL142 CONNECTOR TERMINAL
CHANNEL 1 OUTPUT	WHITE/BLACK	A
CHANNEL 2 OUTPUT	WHITE/BROWN	B
CHANNEL 3 OUTPUT	WHITE/YELLOW	C
CHANNEL 4 OUTPUT	WHITE/GREEN	D
CHANNEL 5 OUTPUT	WHITE/BLUE	E
CHANNEL 6 OUTPUT	WHITE/VIOLET	F
CHANNEL 7 OUTPUT	WHITE/GRAY	H
CHANNEL 8 OUTPUT	WHITE/BLACK/BROWN	J
CHANNEL 9 OUTPUT	WHITE/BLACK/RED	K
CHANNEL 10 OUTPUT	WHITE/BLACK/ORANGE	L
CHANNEL 11 OUTPUT	WHITE/BLACK/YELLOW	M
CHANNEL 12 OUTPUT	WHITE/BLACK/GREEN	N
SUPPLY VOLTAGE, V_{CC} EMITTERS 1-6 PHOTOTRANSISTORS 7-12	WHITE/ORANGE	BB
SUPPLY VOLTAGE, V_{CC} EMITTERS 7-12 PHOTOTRANSISTORS 1-6	RED	CC
GROUND EMITTERS 1-6 PHOTOTRANSISTORS 7-12	BROWN	DD
GROUND EMITTERS 7-12 PHOTOTRANSISTORS 1-6	BLACK	X

TEXAS INSTRUMENTS
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absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Supply Voltage Range, V_{CC} (See Note 1) . . . . −0.5 V to 7 V
Operating Free-Air Temperature Range . . . . 0°C to 70°C
Storage Temperature Range . . . . −65°C to 100°C

NOTE 1: Voltage values are with respect to both ground terminals connected together.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply Voltage, V_{CC}	4.75	5	5.25	V
High-Level Output Current, I_{OH}			−800	μA
Low-Level Output Current, I_{OL}			16	mA
Operating Free-Air Temperature, T_A	0		70	°C

electrical characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	MIN	TYP‡	MAX	UNIT
V_{OH}	High-Level Output Voltage		V_{CC} = 4.75 V, I_{OH} = −800 μA	2.4	3.4		V
V_{OL}	Low-Level Output Voltage		V_{CC} = 4.75 V, I_{OL} = 16 mA		0.2	0.4	V
I_{OS}	Short-Circuit Output Current†		V_{CC} = 5.25 V	−18		−55	mA
I_{CC}	Supply Current	Total, All Outputs High	V_{CC} = 5.25 V		254	290	mA
		Total, All Outputs Low			360	410	
		Average Per Channel	V_{CC} = 5 V, Data Rate ≤ 10 kHz, 50% Duty Cycle		26		

†Not more than one output should be shorted at a time.
‡All typical values are at V_{CC} = 5 V.

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6

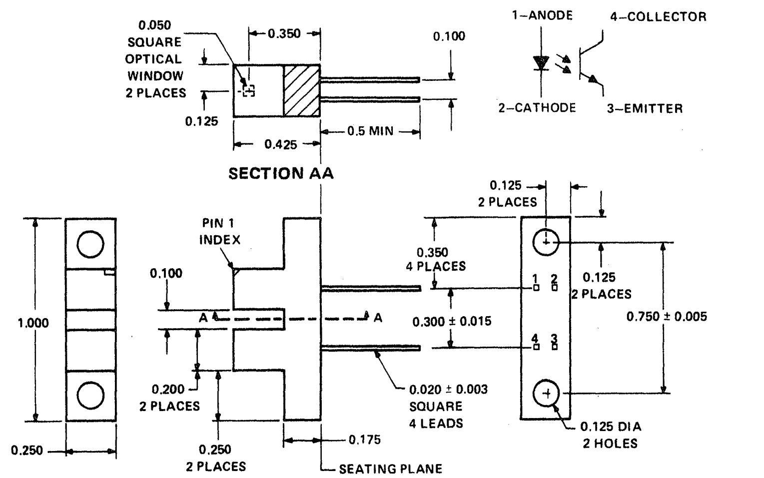
BULLETIN NO. DL-S 7612223, NOVEMBER 1974—REVISED MARCH 1976

OPTOELECTRONIC ENCODER ASSEMBLIES FOR TRANSMISSIVE SENSING APPLICATIONS

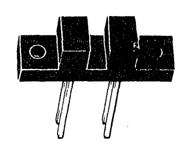
- **Compatible With Standard DTL and TTL Integrated Circuits**
- **High-Speed Switching: t_r = 5 μs, t_f = 5 μs Typical**
- **For Counting, Speed Control, Position Sensing, Beginning-of-Tape/End-of-Tape Sensing, and High-Voltage Isolation**
- **Designed for Base Mounting—Standard 0.300-Inch Dual-In-Line Pin Spacing**
- **PC Board or Bracket Mounting**
- **Contains Gallium Arsenide Infrared Emitter and Silicon Phototransistor**
- **Designed to be Interchangeable with Monsanto MCT8 and MCT81**

mechanical data

Each assembly consists of a gallium arsenide infrared-emitting diode and an n-p-n silicon phototransistor mounted in a housing made of 40% glass-filled polyphenylene sulphide plastic. The assembly will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Total assembly weight is approximately 1.5 grams.



All dimensions are in inches with tolerance of ±0.010 unless otherwise noted.



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Source Reverse Voltage	3 V
Source Continuous Forward Current (See Note 1)	50 mA
Source Peak Forward Current (See Note 2)	3 A
Sensor Collector-Emitter Voltage	30 V
Sensor Emitter-Collector Voltage	5 V
Sensor Continuous Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	100 mW
Source-to-Sensor Voltage	±4.5 kV
Storage Temperature Range	−65°C to 100°C
Lead Temperature 1/16 Inch from Assembly for 5 Seconds	260°C

NOTES: 1. Derate linearly to 100°C free-air temperature at the rate of 0.8 mA/°C.
2. This value applies for $t_w \leq 1$ μs, PRR ≤ 300 pps.
3. Derate linearly to 100°C free-air temperature at the rate of 1.33 mW/°C.

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	TIL143			TIL144			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$, $I_F = 0$	30			30			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 100\ \mu A$, $I_F = 0$	5			5			V
$I_{C(off)}$	Off-State Collector Current	$V_{CE} = 10$ V, $I_F = 0$		5	100		5	100	nA
$I_{C(on)}$	On-State Collector Current	$V_{CE} = 10$ V, $I_F = 20$ mA	200	250		50	100		μA
V_F	Input-Diode Static Forward Voltage	$I_F = 50$ mA		1.35	1.7		1.35	1.7	V

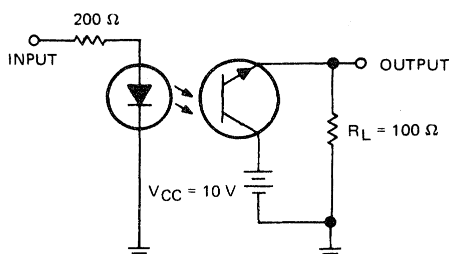
switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
t_r	Rise Time	$V_{CC} = 10$ V, $I_{C(on)} = 1$ mA,		5		μs
t_f	Fall Time	$R_L = 100\ \Omega$, See Figure 1		5		μs

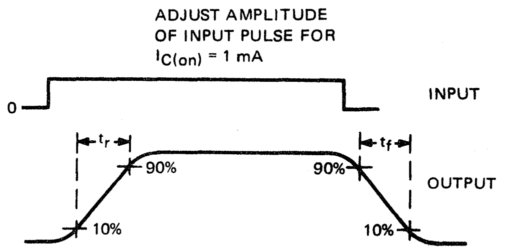
†Stray irradiation outside the range of device sensitivity may be present. A satisfactory condition has been achieved when the parameter being measured approaches a value that cannot be altered by further irradiation shielding.

6

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



NOTE: The input pulse is supplied by a generator having the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 100$ ns, $t_f \leq 100$ ns, $t_w = 10\ \mu s$, duty cycle ≈ 2%.

VOLTAGE WAVEFORMS

FIGURE 1—SWITCHING TIMES

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

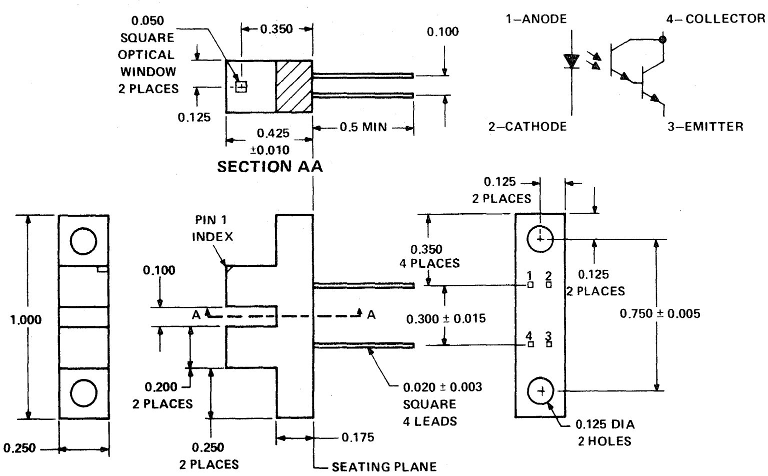
BULLETIN NO. DL-S 7612222, NOVEMBER 1974—REVISED MARCH 1976

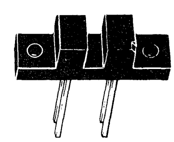
HIGH-GAIN OPTOELECTRONIC ENCODER ASSEMBLIES FOR TRANSMISSIVE SENSING APPLICATIONS

- **Compatible With Standard DTL and TTL Integrated Circuits**
- **High Current Transfer Ratio . . . 0.125 Min (TIL145)**
- **For Counting, Speed Control, Position Sensing, Beginning-of-Tape/End-of-Tape Sensing, and High-Voltage Isolation**
- **Designed for Base Mounting—Standard 0.300-Inch Dual-In-Line Pin Spacing**
- **PC Board or Bracket Mounting**
- **Contains Gallium Arsenide Infrared Emitter and Silicon Darlington Phototransistor**
- **Designed to be Interchangeable with Monsanto MCA8 and MCA81**

mechanical data

Each assembly consists of a gallium arsenide infrared-emitting diode and an n-p-n silicon darlington phototransistor mounted in a housing made of 40% glass-filled polyphenylene sulphide plastic. The assembly will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Total assembly weight is approximately 1.5 grams.





All dimensions are in inches with tolerance of ±0.010 unless otherwise noted.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Source Reverse Voltage	3 V
Source Continuous Forward Current (See Note 1)	50 mA
Source Peak Forward Current (See Note 2)	3 A
Sensor Collector-Emitter Voltage	30 V
Sensor Emitter-Collector Voltage	5 V
Sensor Continuous Dissipation at (or below) 25°C Free-Air Temperature (See Note 3)	100 mW
Source-to-Sensor Voltage	±4.5 kV
Storage Temperature Range	−65°C to 100°C
Lead Temperature 1/16 Inch from Assembly for 5 Seconds	260°C

NOTES: 1. Derate linearly to 100°C free-air temperature at the rate of 0.8 mA/°C.
2. This value applies for $t_w \leq 1\ \mu s$, PRR ≤ 300 pps.
3. Derate linearly to 100°C free-air temperature at the rate of 1.33 mW/°C.

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electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	TIL145			TIL146			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$, $I_F = 0$	30			30			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 100\ \mu A$, $I_F = 0$	5			5			V
$I_{C(off)}$	Off-State Collector Current	$V_{CE} = 5\ V$, $I_F = 0$		5	100		5	100	nA
$I_{C(on)}$	On-State Collector Current	$V_{CE} = 1\ V$, $I_F = 16\ mA$	2	5					mA
		$V_{CE} = 1\ V$, $I_F = 50\ mA$				1.6	4		
V_F	Input-Diode Static Forward Voltage	$I_F = 50\ mA$		1.35	1.7		1.35	1.7	V

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
t_r	Rise Time	$V_{CC} = 5\ V$, $I_{C(on)} = 500\ \mu A$,			3	ms
t_f	Fall Time	$R_L = 1\ k\Omega$, See Figure 1			2.5	ms

†Stray irradiation outside the range of device sensitivity may be present. A satisfactory condition has been achieved when the parameter being measured approaches a value that cannot be altered by further irradiation shielding.

PARAMETER MEASUREMENT INFORMATION

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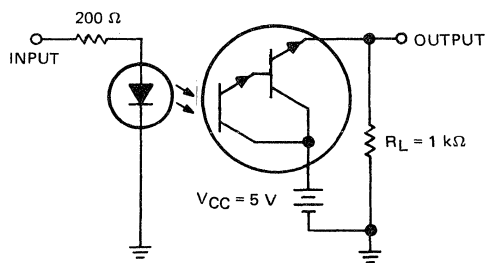
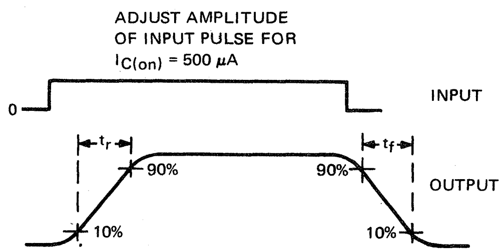


TEST CIRCUIT



NOTE: The input pulse is supplied by a generator having the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leq 10\ \mu s$, $t_f \leq 10\ \mu s$, $t_w = 10$ ms, duty cycle ≈ 50%.

VOLTAGE WAVEFORMS

FIGURE 1–SWITCHING TIMES

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BULLETIN NO. DL-S 7412227, NOVEMBER 1974

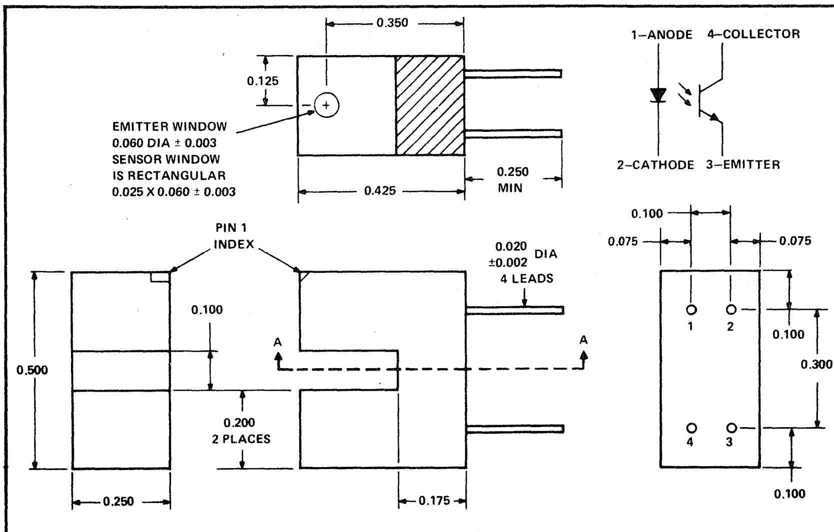
OPTOELECTRONIC ASSEMBLIES FOR TRANSMISSIVE SENSING APPLICATIONS

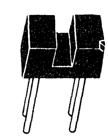
- Compatible with Standard DTL and TTL Integrated Circuits
- High-Speed Switching: $t_r = 5\ \mu s$, $t_f = 5\ \mu s$ Typical
- Designed for Base Mounting . . . Fits Standard Dual-In-Line-Package Socket
- For Sensing Applications such as Shaft Encoders, Sector Sensors, Level Indicators, and Beginning-of-Tape/End-of-Tape Indicators
- Hermetically Sealed Phototransistor and Infrared-Emitting Diode
- 0.025" Aperture Slit Provides High On/Off Resolution
- High Current Transfer Ratio . . . 0.2 Min (TIL147)

6

mechanical data

Each assembly consists of a gallium arsenide infrared-emitting diode of the TIL23 family and an n-p-n silicon phototransistor of the TIL601 family mounted in a housing made of 40% glass-filled polyphenylene sulphide plastic. The assembly will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Total assembly weight is approximately 1.5 grams.





All dimensions are in inches with tolerance of ±0.010 unless otherwise noted.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Source Reverse Voltage	3 V
Source Continuous Forward Current (See Note 1)	100 mA
Sensor Collector-Emitter Voltage	30 V
Sensor Emitter-Collector Voltage	5 V
Sensor Continuous Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	50 mW
Source-to-Sensor Voltage	±2 kV
Storage Temperature Range	−40°C to 100°C
Lead Temperature 1/16 Inch from Assembly for 5 Seconds	260°C

NOTES: 1. Derate linearly to 100°C free-air temperature at the rate of 1.33 mA/°C.
2. Derate linearly to 100°C free-air temperature at the rate of 0.67 mW/°C.

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electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	TIL147		TIL148		UNIT
			MIN	MAX	MIN	MAX	
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$, $I_F = 0$	30		30		V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 100\ \mu A$, $I_F = 0$	5		5		V
$I_{C(off)}$	Off-State Collector Current	$V_{CE} = 10\ V$, $I_F = 0$		100		100	nA
$I_{C(on)}$	On-State Collector Current	$V_{CE} = 5\ V$, $I_F = 20\ mA$	4		1		mA
I_F	Input-Diode Static Forward Voltage	$I_F = 20\ mA$		1.3		1.3	V
		$I_F = 50\ mA$		1.7		1.7	

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
t_r	Rise Time	$V_{CC} = 10\ V$, $I_{C(on)} = 1\ mA$, $R_L = 100\ \Omega$,		5		μs
t_f	Fall Time	See Figure 1		5		μs

†Stray irradiation outside the range of device sensitivity may be present. A satisfactory condition has been achieved when the parameter being measured approaches a value which cannot be altered by further irradiation shielding.

PARAMETER MEASUREMENT INFORMATION

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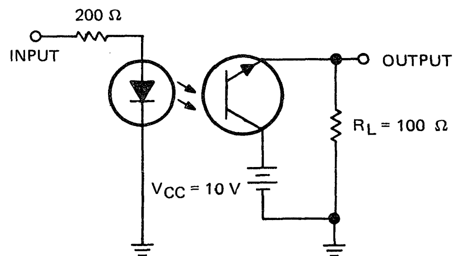
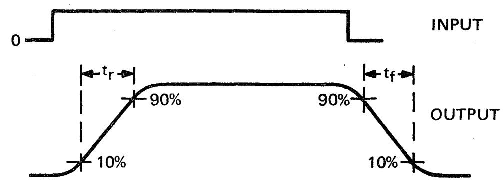


TEST CIRCUIT

ADJUST AMPLITUDE
OF INPUT PULSE FOR
$I_{C(on)} = 1\ mA$



NOTE: The input pulse is supplied by a generator having the following characteristics: $Z_{out} = 50\ \Omega$, $t_r \leqslant 100\ ns$, $t_f \leqslant 100\ ns$, $t_w = 10\ \mu s$, duty cycle ≈ 2%.

VOLTAGE WAVEFORMS

FIGURE 1—SWITCHING TIMES

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PRINTED IN U.S.A. 1174

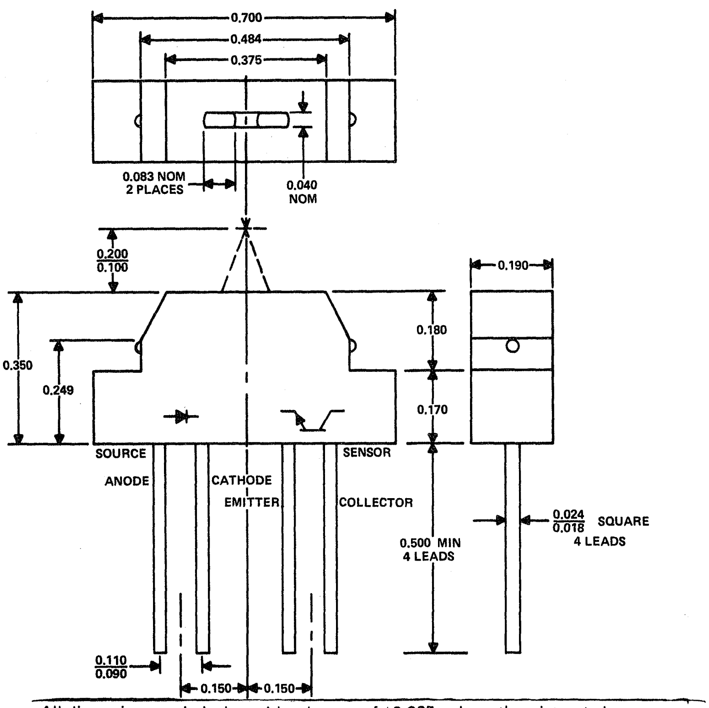
BULLETIN NO. DL-S 7612385, MARCH 1976

OPTOELECTRONIC MODULE FOR REFLECTIVE SENSING APPLICATIONS

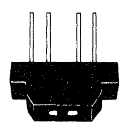
- Adaptable for Printed Circuit Board Mounting
- Designed for Sensing Applications such as Line Finders, Batch Counters, Level Indicators, and Beginning-of-Tape/End-of-Tape Indicators

mechanical data

The assembly consists of a TIL32 gallium arsenide infrared-emitting diode and an n-p-n silicon phototransistor similar to TIL78 mounted in a molded ABS† plastic housing. The assembly will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Total assembly weight is approximately 0.9 grams.



All dimensions are in inches with tolerance of ±0.005 unless otherwise noted.



absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Source Reverse Voltage	2 V
Source Continuous Forward Current (See Note 1)	40 mA
Sensor Collector-Emitter Voltage	30 V
Sensor Emitter-Collector Voltage	7 V
Sensor Continuous Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	50 mW
Storage Temperature Range	−40°C to 85°C
Lead Temperature 1/16 Inch from Assembly for 5 Seconds	240°C

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.73 mA/°C.
2. Derate linearly to 80°C free-air temperature at the rate of 0.91 mW/°C.

†ABS thermoplastics are derived from acrylonitrile, butadiene, and styrene.

electrical characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu A$, $I_F = 0$	30			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	$I_E = 100\ \mu A$, $I_F = 0$	7			V
$I_{C(off)}$	Off-State Collector Current	$V_{CE} = 15\ V$, $I_F = 0$			100	nA
$I_{C(on)}$	On-State Collector Current	$V_{CE} = 5\ V$, $I_F = 40\ mA$, See Note 3	25	275		μA
V_F	Input-Diode Static Forward Voltage	$I_F = 40\ mA$		1.2	1.6	V

†Stray irradiation outside the range of device sensitivity may be present. A satisfactory condition has been achieved when the parameter being measured approaches a value that cannot be altered by further irradiation shielding.

NOTE 3: Reflective surface is 0.001-inch-thick aluminum foil, typical of beginning-of-tape/end-of-tape strips on magnetic tape surface, placed 0.150 inch from read head.

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OPTOELECTRONIC READ HEAD FOR PUNCHED CARDS AND TAPE

Winston Veazey

Because optical punched-tape readers employing filament lamps are faster, quieter, smaller, less complex, and have fewer moving parts than older mechanical readers, optical systems have dominated the reader market since shortly after their introduction. While these optical systems perform relatively well, they still have disadvantages stemming mainly from filament aging. A better system, one eliminating filament-related problems and offering several other advantages, is a completely solid-state read head. Recent advances in optoelectronics technology have made such a read head technically and economically feasible. This report discusses the design, advantages and applications of a completely solid-state head comprised of Texas Instruments infrared-emitting diodes (IRED's) and phototransistors.

INTERFACE WITH PERIPHERAL EQUIPMENT

The solid-state read head presents no problem interfacing with peripheral equipment. Standard size tapes are employed allowing continued use of existing tape equipment and software. Data outputs can be either serial or parallel and will depend on the associated electronics. The output levels will be determined by the channel amplifiers. Present-day IRED's are compatible with DTL, TTL, and MOS integrated circuits and discrete systems. Appropriate circuits allow compatibility with telephone levels where necessary. Other interface circuits can include TI series SN75107-SN75110 line drivers and receivers. Where electrical isolation is needed, TI series TIL107/TIL108 opto-couplers are suitable. System noise, primarily noise caused from circulating ground currents, is eliminated with use of the opto-couplers. These devices are also TTL compatible.

COMPARISON WITH FILAMENT LAMPS

Solid-state infrared emitters have several important advantages over filament lamps used in read heads. One of the most important factors is increased reliability—the IRED's lifetime should be many times the life of the best filament lamp. In addition to the probable lifetime advantage, IRED's eliminate problems related to the filament as the lamp ages, such as filament sag. When the filament sags, light focuses incorrectly on the tape or card holes and consequently, errors in reading occur. Several methods have been used to try to overcome this disadvantage. One method has been to use the lamp at a very high intensity. This increased intensity produces enough light on the sensors and tends to minimize the effects of the sagging filament, but it results in shorter lamp life and difficulty in adjusting the threshold level for low-opacity tapes and cards. Another effort to solve the problem has been to use spring tension on the filament. This type of lamp incorporating spring tension is expensive and mechanical resonance problems sometimes occur. By using IRED's, the problems associated with filaments can be eliminated and this appears to be one of the most desirable benefits of an all-solid-state read head.

Because IRED's are much more vibration resistant than filament lamps, they have stability over a wide range of environmental conditions which is another advantage IRED's have compared to filament lamps. The TIL23/TIL24 emitters have temperature characteristics which are opposite to those of the LS600/TIL601 sensors, and consequently, when used as a pair, the TIL23/LS600 devices give stable outputs over a wide temperature range. Table 1 shows a comparison between tungsten lamps and IRED's when used with a phototransistor sensor. It shows variation in output current of the phototransistor as a function of several parameters and illustrates the superior overall stability of IRED's compared to the stability of tungsten-filament lamps. This stability results in much easier adjustment of the circuit and much more stable operating conditions.

IRED's require much lower power than the filament lamp resulting in much less heat dissipation in the head. Some filament lamps require as much as 15 watts of power as compared to less than 1/2 watt for nine IRED's. Because most of this power is dissipated as heat in the system, poor efficiency results. Since the required power is low, a relatively simple current driver/regulator can be utilized, with the necessary components in the driver being small and of low power. A discussion of the required circuitry appears later in this report.

Table 1. Comparison Between Tungsten Lamps and Infrared-Emitting Diodes, Showing Variation in Output Current of Phototransistor

Spread Due To	Tungsten Lamp	IRED
Temperature 0–75°C	3:1	1.5:1
Supply voltage ±5%	1.6:1	1.1:1
Aging 10,000 hours	2:1	1.5:1
Close match	8:1	4:1
Total spread	77:1	10:1

The small size of IRED's is another advantage. Because of its small size, the emitter can be placed in close proximity to the sensors, thus reducing the effect of any extraneous light which could cause reading errors. The LS600 phototransistors and TIL23/24 infrared emitters are in packages suitable for mounting on printed circuit boards. This packaging permits easy mounting on printed circuit boards. Moreover, the physical compatibility eliminates any need for fiber optics, focus rods, or external lens to focus the radiant energy on the sensors. In addition, there is no need for amplifier compensation, which is often necessary when the infrared source is shorter than the tape or card width. The optical compatibility is illustrated in Figure 1. This graph shows the spectrum response of tungsten filament lamps, GaAs IRED's, Si sensors, and the human eye. GaAs emitters emit in the near-infrared region, their peak output wavelength being very near that of Si sensors (phototransistors) resulting in efficient coupling between the devices.

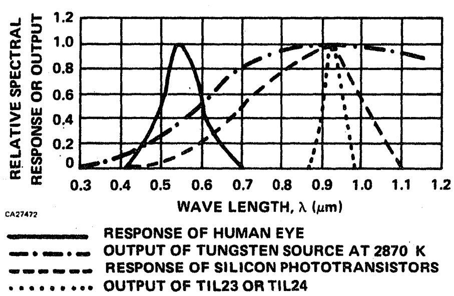

FIGURE 1. Relative Spectral Characteristics

PHYSICAL CHARACTERISTICS

In the design of an optical solid-state read head, the mechanical configuration is very important. The sensor output, hence circuit requirements, are heavily dependent on the optical coupling characteristics. Representative coupling characteristics for TIL24 and LS600 devices are shown in Figure 2. This chart indicates that typical TIL24/LS600 device pairs are available which have outputs

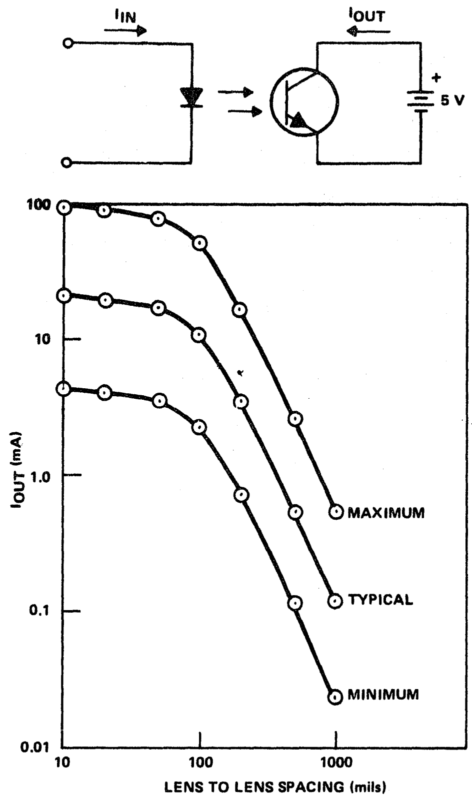

FIGURE 2. TIL24/LS600 Coupled Pairs. Expected Output Current for 50 mA Input Current.

of 2 mA at a lens-to-lens spacing of 1/4 inch. These output levels are high enough to allow versatility in the amplifier/interface. Since the mechanical aspects of the system influence electrical output, much consideration should be given to the mechanical design. An important criterion related to electrical output is the system's contrast ratio. The contrast ratio is the ratio of "hole" output current to "no-hole" output current of the phototransistor. For a good electrical design, this ratio should be as high as possible. Current ratios of 50:1 should make the required circuit design relatively simple. On the other hand, a low contrast ratio provides only a narrow range for the threshold level, making circuit design more difficult. Among the factors that affect the current ratio are 1) IRED and sensor parameters, 2) lens-to-lens spacing of the IRED's and sensors, 3) placement of the tape or card between device pairs, 4) use of an aperture plate between pairs of devices, 5) tape opacity, and 6) optical crosstalk between channels. These factors are interrelated and will affect current ratios. Each individual application will, to a certain extent, dictate some of the above factors. To get optimum results, use of device pairs rendering adequate output currents, an opaque aperature plate, high-opacity tape, and a tube for each channel to prevent optical crosstalk are desired. Using an opaque aperture plate between the IRED's and phototransistors is probably the single most important factor in obtaining high contrast ratios for low-opacity tapes. Contrast ratios versus IRED current for various types of tape with several lens-to-lens spacings are shown in Figure 3. The data was taken using an aperture plate with holes of 0.035-inch diameter and having a separate tube for each channel to eliminate crosstalk. It is apparent that the oiled paper tapes are least desirable from a current ratio standpoint. This is to be expected since oiled paper tapes are the least opaque of the tapes commonly used in the industry. The graphs indicate that it is possible to obtain contrast ratios of 50:1 or greater for oiled-paper tapes when using an aperture plate.

Good performance should result if the mechanical design insures adequate coupling when the tape or card is to be read. This involves the relative physical alignment concerning the IRED's, sensors, aperture plate, and the tape or card being read.

CIRCUIT REQUIREMENTS

The many different tape and card reader applications can dictate various circuit requirements because of some specific mechanical or electrical restraint. It would be difficult, if not impossible, to try to design a circuit that would meet all requirements for all types of punched tape or card readers. However, some of the general problems that might be encountered in designing the circuitry necessary for a reader will be examined.

Many of the factors that affect the physical configuration influence the phototransistor output current that, in turn, determines the channel amplifiers and related circuitry. The amplifiers must be capable of differentiating between "hole" and "no-hole" currents and producing the level of output necessary to interface with peripheral equipment.

With sufficient sensor output currents, the devices can be compatible with TTL and DTL integrated circuits. Figure 4-a represents one method by which phototransistors can be used with TTL. The sensor must be capable of sinking 1.6 milliamps at 0.8 volts to ensure a low level at the input of the gate. The SN7413 is a Schmitt trigger type of NAND gate—its output will switch when the input reaches a set level, regardless of the rise time of the input signal. The result is clean, positive, and fast switching at the output without any oscillations, which might otherwise appear at the output during the switching time. Use of the Schmitt trigger is desirable because typical TTL and DTL integrated circuits require inputs to switch in much less than one microsecond for clean outputs during rise and fall times and the switching times of typical phototransistors are greater than one microsecond.

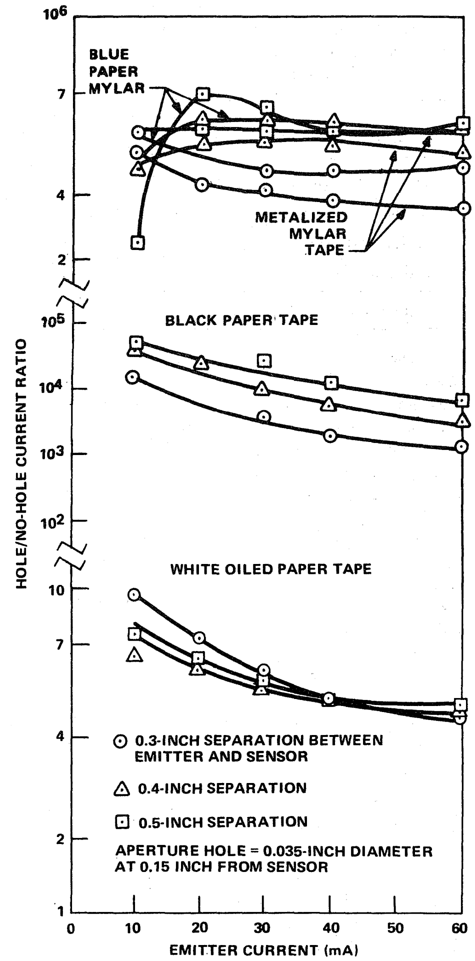

FIGURE 3. Different Contrast Ratios of White Oiled Paper, Black Paper, and Metallized Mylar Tape at Various Currents of TIL24/LS600 Coupled Pairs

Additional versatility can be obtained by making the amplifier much more sensitive. A simple circuit for achieving this is shown in Figure 4-b. The additional transistor gives another stage of amplification, increasing the sensitivity by approximately the h_{FE} of the transistor.

For increased versatility with the use of integrated circuits, the system can be designed so that only one Schmitt trigger is necessary, that being for the strobe amplifier. To use this technique effectively, the aperture hole for the strobe channel should be smaller than the holes for all the other channels. This size differential allows the data channel outputs to stabilize before the strobe amplifier

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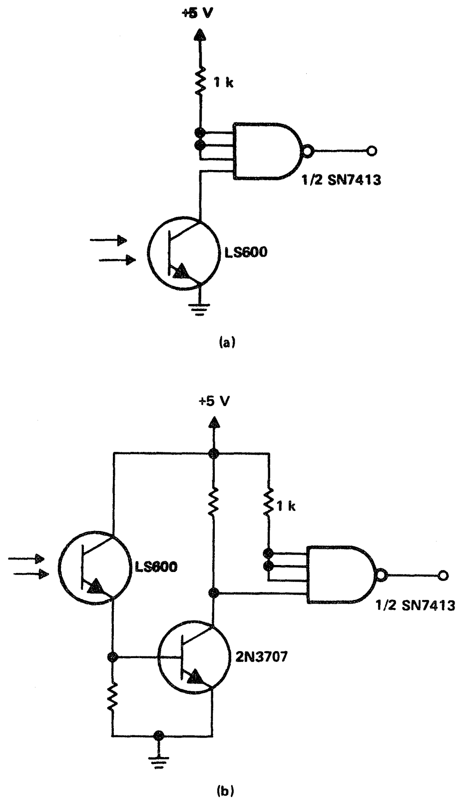

FIGURE 4. Schmitt Trigger Channel Amplifiers

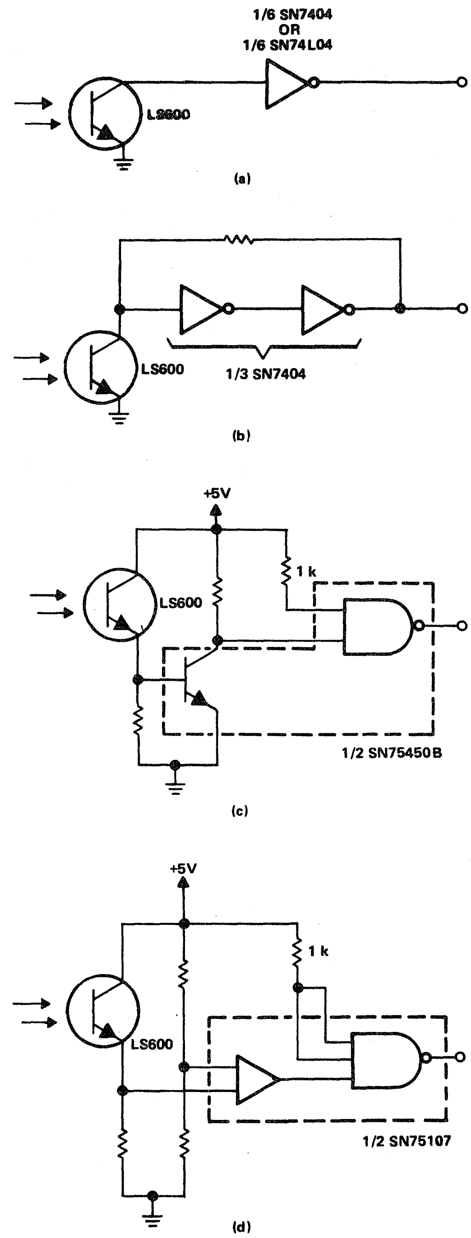

FIGURE 5. Other Channel Amplifiers Using Integrated Circuits

triggers. If any oscillations occur during the switching times of the data channel amplifiers, they will no longer be present when the strobe channel amplifier switches.

Integrated circuits other than the SN7413 can be used for the channel amplifiers. Circuits illustrating the use of several different devices are shown in Figure 5. The circuit shown in Figure 5-a uses only one gate of an SN7404 package. The sensor must be capable of sinking 1.6 mA at 0.8 volts–if not, the SN74L04 ensures operation for a maximum sink current of 0.18 mA at 0.8 volts. The circuit in Figure 5-b makes use of a feedback resistor to provide faster switching–the output is inverted from that of Figure 5-a. Figures 5-c and 5-d show circuits which can be used where radiant energy levels may not be sufficient to ensure 1.6-mA sensor current. Both have stages of gain for amplification before the gate. It should be noted that these circuits may have oscillations at the outputs during switching.

Other circuits can be designed to meet necessary requirements of channel amplifiers. Even if discrete components are used, it is desirable to use a Schmitt trigger arrangement to provide clean and positive switching at a predictable level.

The IRED's can be driven from a current source or voltage source, either in series or parallel. The most desirable method will be dependent on the system. In general, it is simpler and more efficient to drive the IRED's in series from a constant-current source. Series connection ensures the same current through all the IRED's and thus tends to maintain a more uniform output. In addition, with the series connection, only two leads out of the IRED array are necessary. For parallel connection of IRED's, a current-limiting resistor in series with each IRED must be used because of the difference in forward voltage drop of the devices.

Figure 6 illustrates a circuit to drive the IRED's in series from a constant-current source that regulates variations in IRED voltages and supply voltage. The IRED current is determined by $(V_Z - 0.7)R1$, where V_Z is the zener voltage. The zener diode voltage will be determined primarily by the supply voltage and the number of IRED's in series.

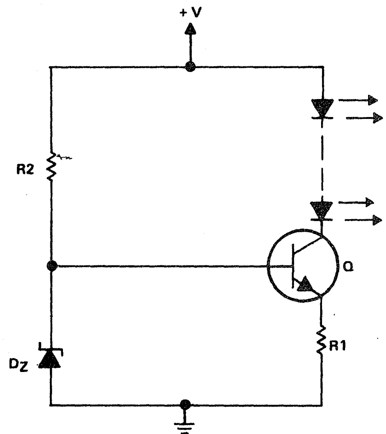

FIGURE 6. LED Driver/Regulator

DESCRIPTION OF A SOLID-STATE READ HEAD IN AN ACTUAL APPLICATION

An off-the-shelf punched tape reader was bought and modified by replacing the read head and channel amplifiers. The tape reader was of the optical type with a filament lamp and photodiodes. Nine elements of LS600 phototransistors mounted on a small printed circuit board replaced the original photodiode array. This sensor array was mounted so that the phototransistor lenses were 150 mils from the tape. Since the LS600's and TIL24's have identical packages, they were mounted on similar printed circuit boards. The IRED's (TIL24's) were placed 150 mils from the tape resulting in a lens-to-lens spacing of 300 mils. An aperture plate with 0.045-inch channel holes and 0.035-inch strobe hole was used. The IRED's were driven at 10 milliamps each from the circuit shown in Figure 7. Because the tape reader only had +6 and +28 volts available, 28 volts was used.

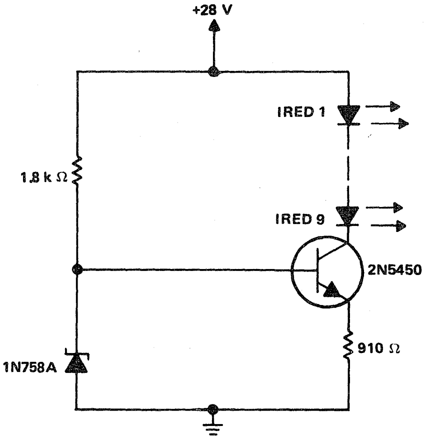

FIGURE 7. IRED Driver/Regulator Used in System

The modified reader has nine parallel outputs, one for each of the eight data channels, and one for the strobe channel. Figure 8 illustrates the schematic for the channel amplifiers that were used. The SN7413 Schmitt trigger eliminates oscillations at the output during switching. To set the threshold level the collector resistor and base resistor can be adjusted. These resistor values are partially dependent on the "hole" and "no-hole" currents of the phototransistor. It may have been desirable to use IRED's and phototransistors that were matched (have outputs that are within a given range for a set input). This would have simplified the adjustment of the amplifiers by ensuring uniformity among the channels. Using matched devices is more desirable for lower contrast ratios, since the adjustment for these is more critical. Figures 3 and 4 show the typical contrast ratios that were achieved.

Since the tape reader has been used in a visual display system that requires slow strobe rates, speed of operation of this reader has not been a prime consideration.

SUMMARY

Optical punched tape and card readers have captured a large share of the reader market because of their many advantages over the older mechanical readers. This success, coupled with a reduction in prices of electronic components, has made the all-solid-state read head economically, as well as technically, practical and beneficial. A read head

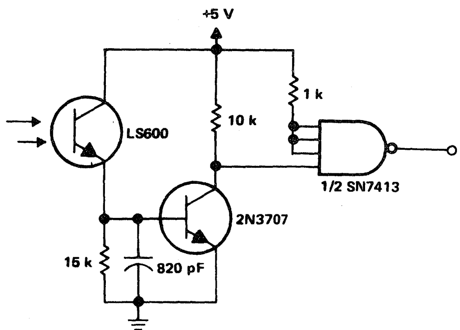

FIGURE 8. Channel Amplifier Used in System

consisting of infrared-emitting diodes and phototransistors presents no problem with respect to being used with existing peripheral equipment. IRED's provide several important advantages over filament lamps for use in read heads: (1) IRED's have longer life and inherently eliminate the problems associated with filament sag due to aging, resulting in higher overall reliability. (2) IRED's possess a higher degree of environmental stability, including temperature and vibration stability. (3) IRED's have very low power requirements, dissipating less heat and having higher electrical efficiency. (4) The IRED's small size enables them to be placed in close proximity to the sensors, making the system smaller and less affected by extraneous radiation.

Physical configuration is very important in the performance of the overall system. The circuit requirements are dependent on the coupling characteristics of the IRED's and sensors. A high contrast ratio ("hole" current to "no-hole" current) is desirable for simplicity in the circuit design. The use of an aperture plate between IRED's and sensors and elimination of optical crosstalk between channels are two factors which will help in achieving a high contrast ratio, especially for low opacity tapes.

Phototransistors can be compatible with integrated circuits. A Schmitt trigger integrated circuit (SN7413) allows simplicity in channel amplifier design to achieve clean and positive switching. A simple current source/regulator will suffice to drive the IRED's. Driving the IRED's in series from a constant-current source provides uniformity in radiant-energy output.

A standard optical tape reader was modified by replacing the read head and channel amplifiers. TIL24's and LS600's were used for the IRED's and sensors respectively and a SN7413 Schmitt trigger NAND gate was used in the channel amplifiers. With an aperture plate, contrast ratios for various types of tapes ranged from 40:1 to 500,000:1.

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TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

Light-Emitting Diodes

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LIGHT-EMITTING DIODES QUICK REFERENCE GUIDE

DEVICE	COLOR OF LIGHT	OUTPUT MIN	OUTPUT TYP	OUTPUT @ I_F	V_F MAX	V_F @ I_F	λ_p TYP	FEATURES
TIL209A	Red	500 μcd		20 mA	2 V	20 mA	6500 Å	0.120-inch-dia body. Red diffused epoxy
TIL211	Green	800 μcd	1500 μcd	25 mA	4 V	25 mA	5650 Å	0.120-inch-dia body. Green diffused epoxy
TIL220	Red	800 μcd		20 mA	2 V	20 mA	6500 Å	0.200-inch-dia body. Red diffused epoxy
TIL221	Red	1000 μcd		20 mA	2 V	20 mA	6500 Å	0.200-inch-dia body. Clear epoxy
TIL222	Green	1000 μcd	1500 μcd	25 mA	4 V	25 mA	5650 Å	0.200-inch-dia body. Green diffused epoxy
TIL261	Red	500 μcd		20 mA	2 V	20 mA	6500 Å	Single element. Red diffused epoxy
TIL262	Red	500 μcd†		20 mA	2 V	20 mA	6500 Å	2-element array. Red diffused epoxy
TIL263	Red	500 μcd†		20 mA	2 V	20 mA	6500 Å	3-element array. Red diffused epoxy
TIL264	Red	500 μcd†		20 mA	2 V	20 mA	6500 Å	4-element array. Red diffused epoxy
TIL265	Red	500 μcd†		20 mA	2 V	20 mA	6500 Å	5-element array. Red diffused epoxy
TIL266	Red	500 μcd†		20 mA	2 V	20 mA	6500 Å	6-element array. Red diffused epoxy
TIL267	Red	500 μcd†		20 mA	2 V	20 mA	6500 Å	7-element array. Red diffused epoxy
TIL268	Red	500 μcd†		20 mA	2 V	20 mA	6500 Å	8-element array. Red diffused epoxy
TIL269	Red	500 μcd†		20 mA	2 V	20 mA	6500 Å	9-element array. Red diffused epoxy
TIL270	Red	500 μcd†		20 mA	2 V	20 mA	6500 Å	10-element array. Red diffused epoxy
TIL271	Green	800 μcd†	1500 μcd	25 mA	4 V	25 mA	5650 Å	Single element. Green diffused epoxy
TIL272	Green	800 μcd†	1500 μcd†	25 mA	4 V	25 mA	5650 Å	2-element array. Green diffused epoxy
TIL273	Green	800 μcd†	1500 μcd†	25 mA	4 V	25 mA	5650 Å	3-element array. Green diffused epoxy
TIL274	Green	800 μcd†	1500 μcd†	25 mA	4 V	25 mA	5650 Å	4-element array. Green diffsued epoxy
TIL275	Green	800 μcd†	1500 μcd†	25 mA	4 V	25 mA	5650 Å	5-element array. Green diffused epoxy
TIL276	Green	800 μcd†	1500 μcd†	25 mA	4 V	25 mA	5650 Å	6-element array. Green diffused epoxy
TIL277	Green	800 μcd†	1500 μcd†	25 mA	4 V	25 mA	5650 Å	7-element array. Green diffused epoxy
TIL278	Green	800 μcd†	1500 μcd†	25 mA	4 V	25 mA	5650 Å	8-element array. Green diffused epoxy
TIL279	Green	800 μcd†	1500 μcd†	25 mA	4 V	25 mA	5650 Å	9-element array. Green diffused epoxy
TIL280	Green	800 μcd†	1500 μcd†	25 mA	4 V	25 mA	5650 Å	10-element array. Green diffused epoxy
TIL281	Amber	800 μcd†	1500 μcd†	25 mA	3 V	25 mA	5900 Å	Single element. Amber diffused epoxy
TIL282	Amber	800 μcd†	1500 μcd†	25 mA	3 V	25 mA	5900 Å	2-element array. Amber diffused epoxy
TIL283	Amber	800 μcd†	1500 μcd†	25 mA	3 V	25 mA	5900 Å	3-element array. Amber diffused epoxy
TIL284	Amber	800 μcd†	1500 μcd†	25 mA	3 V	25 mA	5900 Å	4-element array. Amber diffused epoxy
TIL285	Amber	800 μcd†	1500 μcd†	25 mA	3 V	25 mA	5900 Å	5-element array. Amber diffused epoxy
TIL286	Amber	800 μcd†	1500 μcd†	25 mA	3 V	25 mA	5900 Å	6-element array. Amber diffused epoxy
TIL287	Amber	800 μcd†	1500 μcd†	25 mA	3 V	25 mA	5900 Å	7-element array. Amber diffused epoxy
TIL288	Amber	800 μcd†	1500 μcd†	25 mA	3 V	25 mA	5900 Å	8-element array. Amber diffused epoxy
TIL289	Amber	800 μcd†	1500 μcd†	25 mA	3 V	25 mA	5900 Å	9-element array. Amber diffused epoxy
TIL290	Amber	800 μcd	1500 μcd†	25 mA	3 V	25 mA	5900 Å	10-element array. Amber diffused epoxy

†Output per element

The following devices will be introduced in 1976:
- TIL212 Small amber LED, same package as TIL209A
- TIL224 Large amber LED, same package as TIL220.

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BULLETIN NO. DL-S 7412024, JUNE 1973—REVISED NOVEMBER 1974

TYPE TIL209A
GALLIUM ARSENIDE PHOSPHIDE VISIBLE-LIGHT SOURCE

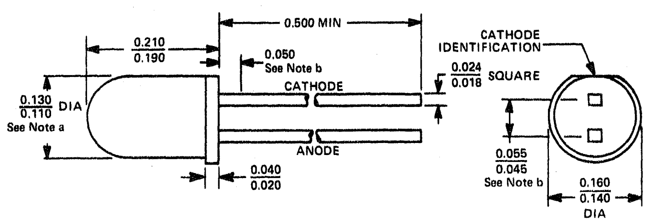
DESIGNED TO EMIT VISIBLE RED LIGHT WHEN FORWARD BIASED

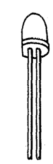
- **Recommended for Application in Visual Indicators, Alpha-Numeric Displays, and Built-In Diagnostics**
- **High Brightness with Solid-State Reliability**
- **Compatible with Most TTL and DTL Circuits**
- **Ideal as Fault or Trouble Indicator**
- **Filled-Epoxy Lens Provides Diffused Source**
- **Ideal for Socket, Printed Circuit Board, and 1/16" Panel Mounting Techniques**

MV50
TiL209A
TIL49

mechanical data

This device has a red molded filled-epoxy body.





NOTES: a. This diameter is measured 0.005 inch from the shoulder.
b. Within this zone the package contour is not controlled.
c. Lead spacing is measured where the leads emerge from the package.
d. All dimensions are in inches.

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature	3 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	40 mA
Storage Temperature Range	−40°C to 80°C
Lead Temperature 1/16 Inch from Case for 5 Seconds	230°C

operating characteristics at 25°C free-air temperature

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V	Luminous Intensity (See Note 2)	$I_F = 20$ mA	500			μcd
λ_p	Wavelength at Peak Emission	$I_F = 20$ mA	6300	6500	6700	Å
V_F	Static Forward Voltage	$I_F = 20$ mA		1.6	2	V
I_R	Static Reverse Current	$V_R = 3$ V		0.1		μA

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.73 mA/°C.
2. Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

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TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

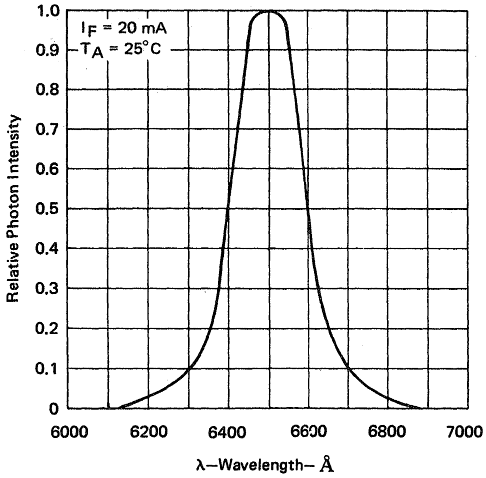

FIGURE 1

RELATIVE LUMINOUS INTENSITY
vs
FREE-AIR TEMPERATURE

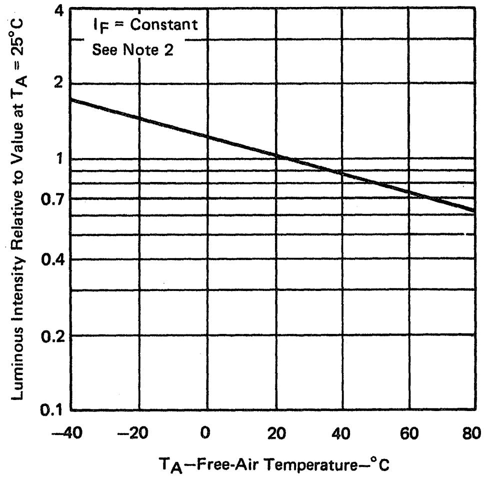

FIGURE 2

RELATIVE LUMINOUS INTENSITY
vs
FORWARD CURRENT

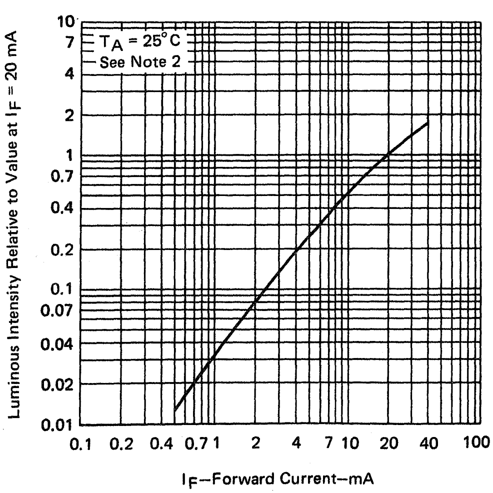

FIGURE 3

FORWARD CONDUCTION CHARACTERISTICS

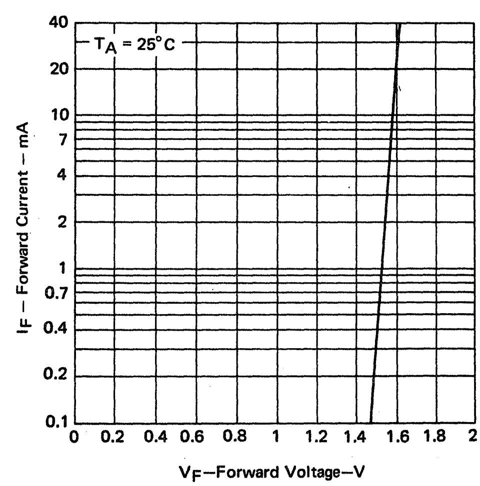

FIGURE 4

NOTE 2: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

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TYPE TIL211
GALLIUM PHOSPHIDE VISIBLE-LIGHT SOURCE

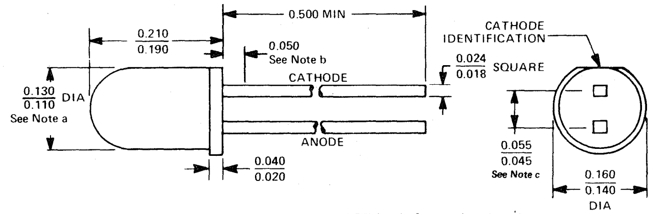
BULLETIN NO. DL-S 7412095, MARCH 1974—REVISED NOVEMBER 1974

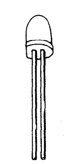
DESIGNED TO EMIT GREEN LIGHT WHEN FORWARD BIASED

- Recommended for Application in Visual Indicators, Alpha-Numeric Displays, and Built-In Diagnostics
- High Brightness with Solid-State Reliability
- Compatible with Most TTL and DTL Circuits
- Ideal as Fault or Trouble Indicator
- Filled-Epoxy Lens Provides Diffused Source
- Ideal for Socket, Printed Circuit Board, and 1/16″ Panel Mounting Techniques
- Leads are Designed to be Wire-Wrapped

mechanical data

This device has a green molded filled-epoxy body.





NOTES: a. This diameter is measured 0.005 inch from the shoulder.
b. Within this zone the package contour is not controlled.
c. Lead spacing is measured where the leads emerge from the package.
d. All dimensions are in inches.

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absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature	3 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	50 mA
Peak Forward Current at (or below) 25°C Free-Air Temperature (See Note 2)	2 A
Power Dissipation	See Note 3
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 80°C
Lead Temperature 1/16 Inch from Case for 5 Seconds	230°C

operating characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V	Luminous Intensity (See Note 4)	I_F = 25 mA	800	1500		μcd
λ_p	Wavelength at Peak Emission	I_F = 25 mA		5650		Å
V_F	Static Forward Voltage	I_F = 25 mA		2.3	3	V
		I_F = 50 mA		2.6	5	
α_{VF}	Average Temperature Coefficient of Static Forward Voltage	I_F = 25 mA, T_A = −40°C to 80°C		2.5		mV/°C
I_R	Static Reverse Current	V_R = 3 V			100	μA
C	Capacitance	V_F = 0, f = 1 MHz		100		pF
t_r	Luminous Pulse Rise Time†	I_{FM} = 25 mA, t_w = 2 μs, f = 45 kHz		300		ns
t_f	Luminous Pulse Fall Time†			300		

†Luminous pulse rise time is the time required for a change in luminous intensity from 10% to 90% of its peak value for a step change in current; luminous pulse fall time is the time required for a change in luminous intensity from 90% to 10% of its peak value for a step change in current.

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.91 mA/°C.
2. This value applies for $t_w \leq 1$ μs, duty cycle ≤ 0.5%.
3. The package is capable of dissipating whatever power ($V_F \times I_F$) is developed at any level of forward current at or below the rated amount. Typical junction-to-free-air thermal resistance, $R_{\theta JA}$, is 230°C/W.
4. Luminous Intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

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TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

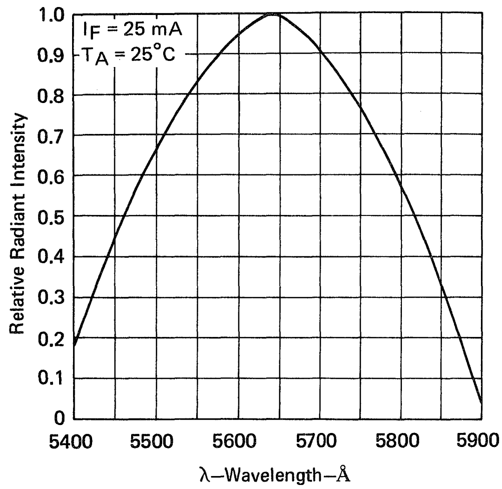

FIGURE 1

RELATIVE LUMINOUS INTENSITY vs FREE-AIR TEMPERATURE

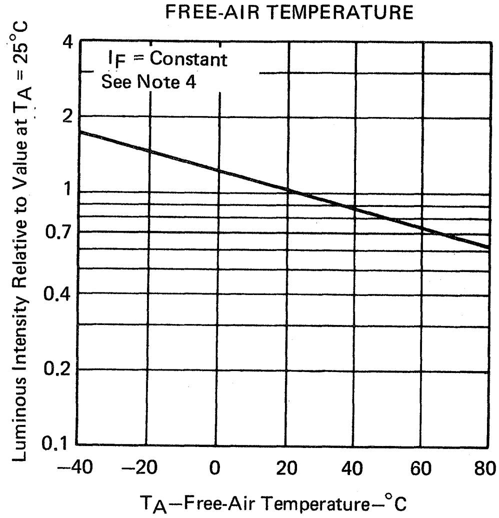

FIGURE 2

RELATIVE LUMINOUS INTENSITY vs FORWARD CURRENT

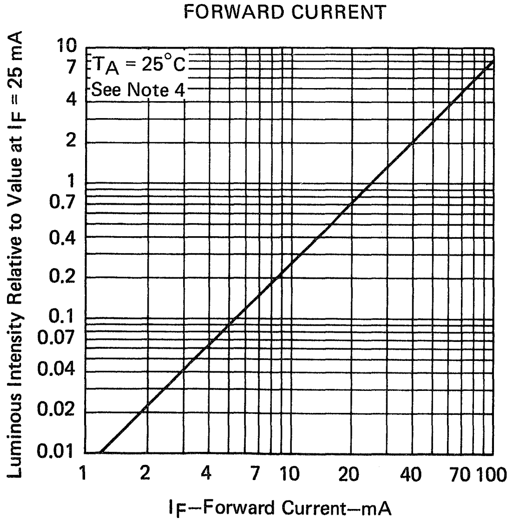

FIGURE 3

FORWARD CONDUCTION CHARACTERISTICS

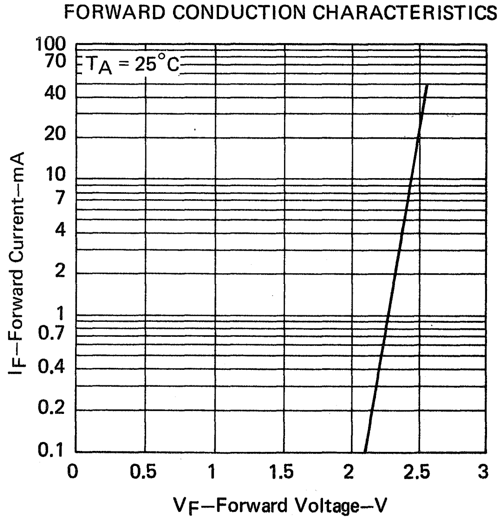

FIGURE 4

NOTE 4: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

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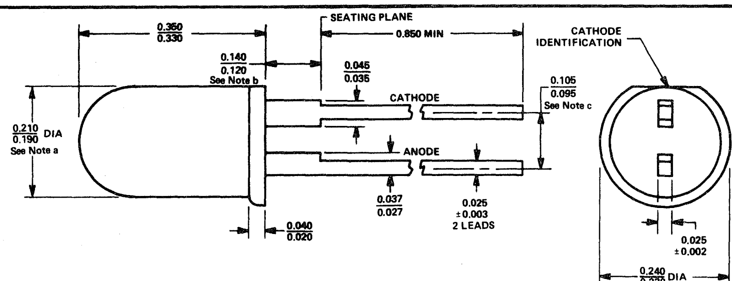
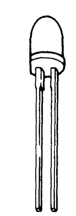
DESIGNED TO EMIT VISIBLE RED LIGHT WHEN FORWARD BIASED

- Recommended for Panel Mounted Visual Indicators
- High Brightness with Solid-State Reliability
- Compatible with Most TTL and DTL Circuits
- Leads Are Designed to be Wire-Wrapped
- Filled-Epoxy Lens Provides Diffused Source (TIL220)
- Clear Epoxy Lens Provides Pin-Point Source (TIL221)

mechanical data

TIL220 has a red molded filled-epoxy body. TIL221 has a colorless clear molded epoxy body.





NOTES: a. This diameter is measured 0.005 inch from shoulder.
b. The contour is not controlled within this region of the leads.
c. Lead spacing is measured where the leads emerge from the package.
d. All dimensions are in inches.

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absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature	3 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	50 mA
Power Dissipation	See Note 2
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 80°C
Lead Temperature 1/16 Inch from Case for 5 Seconds	230°C

operating characteristics at 25°C free-air temperature

PARAMETER	TEST CONDITIONS	TIL220			TIL221			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
I_V Luminous Intensity (See Note 2)	I_F = 20 mA	800			1000			µcd
λ_p Wavelength at Peak Emission	I_F = 20 mA	6300	6500	6700	6300	6500	6700	Å
V_F Static Forward Voltage	I_F = 20 mA		1.6	2		1.6	2	V
I_R Static Reverse Current	V_R = 3 V		0.1			0.1		µA

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.91 mA/°C.
2. The package is capable of dissipating whatever power ($V_F \times I_F$) is developed at any level of forward current at or below the rated amount. Typical junction-to-free-air thermal resistance, $R_{\theta JA}$, is 230°C/W.
3. Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

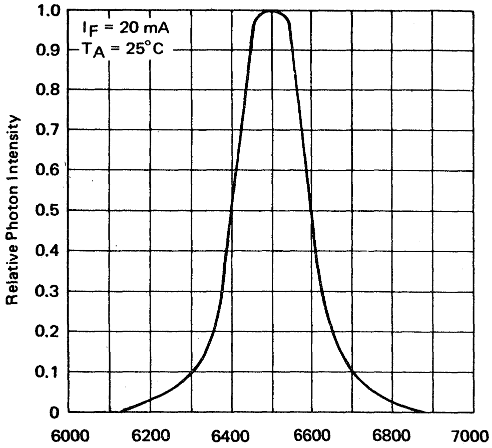

FIGURE 1

RELATIVE LUMINOUS INTENSITY
vs
FREE-AIR TEMPERATURE

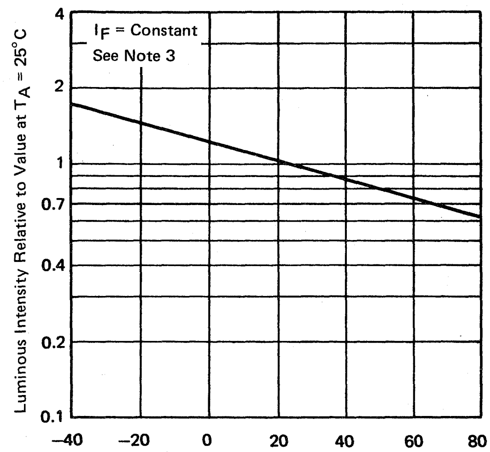

FIGURE 2

RELATIVE LUMINOUS INTENSITY
vs
FORWARD CURRENT

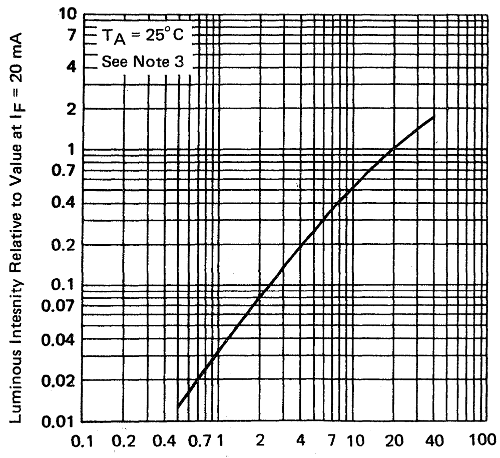

FIGURE 3

FORWARD CONDUCTION CHARACTERISTICS

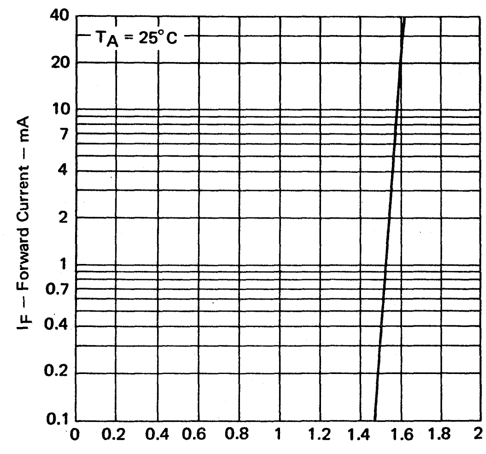

FIGURE 4

NOTE 3: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

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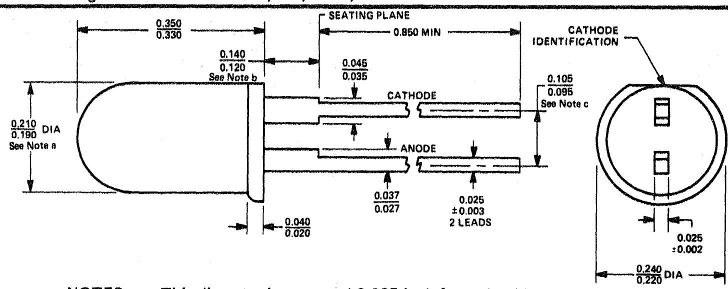
BULLETIN NO. DL-S 7612100, MARCH 1974—REVISED MARCH 1976

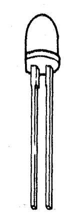
DESIGNED TO EMIT GREEN LIGHT WHEN FORWARD BIASED

- **Recommended for Panel Mounted Visual Indicators**
- **High Brightness with Solid-State Reliability**
- **Compatible with Most TTL and DTL Circuits**
- **Leads Are Designed to be Wire-Wrapped**
- **Green Filled-Epoxy Leans Provides Diffused Source**

mechanical data

This device has a green molded filled-epoxy body.





NOTES: a. This diameter is measured 0.005 inch from shoulder
b. The contour is not controlled within this region of the leads.
c. Lead spacing is measured where the leads emerge from the package.
d. All dimensions are in inches.

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature	3 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	50 mA
Peak Forward Current at (or below) 25°C Free-Air Temperature (See Note 2)	2 A
Power Dissipation	See Note 3
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 80°C
Lead Temperature 1/16 Inch from Case for 5 Seconds	230°C

operating characteristics at 25°C free-air temperature (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V	Luminous Intensity (See Note 4)	I_F = 25 mA	1000	1500		μcd
λ_p	Wavelength at Peak Emission	I_F = 25 mA		5650		Å
V_F	Static Forward Voltage	I_F = 25 mA		2.3	3	V
		I_F = 50 mA		2.6	5	
α_{VF}	Average Temperature Coefficient of Static Forward Voltage	I_F = 25 mA, T_A = −40°C to 80°C		2.5		mV/°C
I_R	Static Reverse Current	V_R = 3 V			100	μA
C	Capacitance	V_F = 0, f = 1 MHz		100		pF
t_r	Luminous Pulse Rise Time†	I_{FM} = 25 mA, t_w = 2 μs, f = 45 kHz		300		ns
t_f	Luminous Pulse Fall Time†			300		

†Luminous pulse rise time is the time required for a change in luminous intensity from 10% to 90% of its peak value for a step change in current; luminous pulse fall time is the time required for a change in luminous intensity from 90% to 10% of its peak value for a step change in current.

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.91 mA/°C.
2. This value applies for $t_w \leq 1$ μs, duty cycle ≤ 0.5%.
3. The package is capable of dissipating whatever power ($V_F \times I_F$) is developed at any level of forward current at or below the rated amount. Typical junction-to-free-air thermal resistance, $R_{\theta JA}$, is 230°C/W.
4. Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

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TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

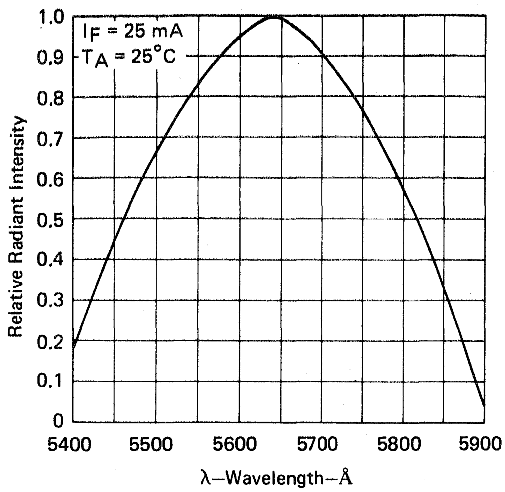

FIGURE 1

RELATIVE LUMINOUS INTENSITY vs FREE-AIR TEMPERATURE

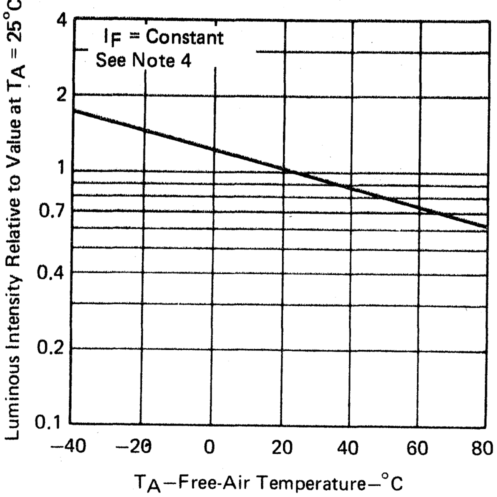

FIGURE 2

RELATIVE LUMINOUS INTENSITY vs FORWARD CURRENT

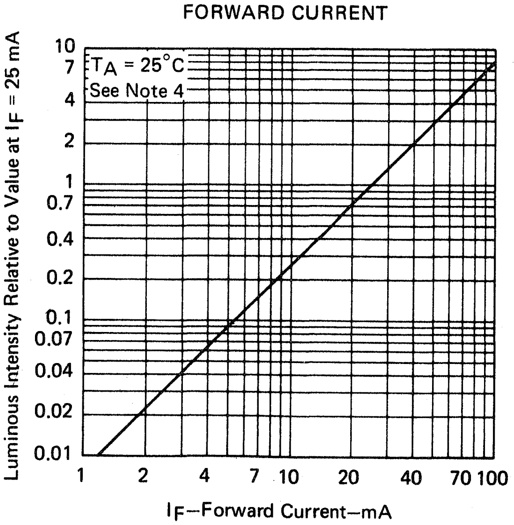

FIGURE 3

FORWARD CONDUCTION CHARACTERISTICS

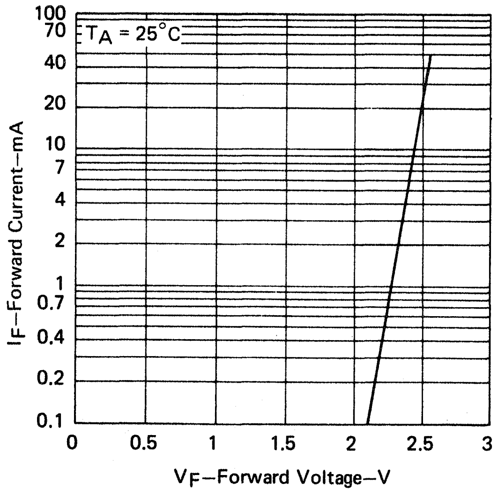

FIGURE 4

NOTE 4: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

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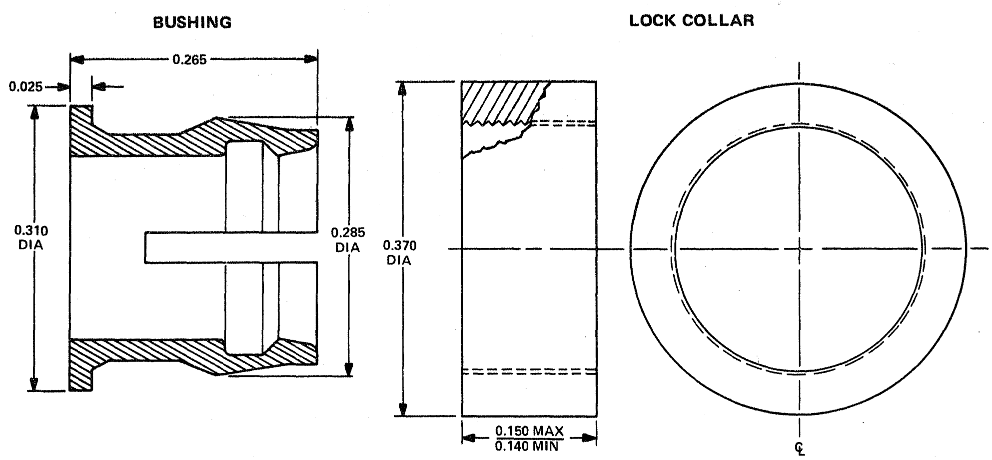
PANEL MOUNTING BUSHING WITH LOCK COLLAR FOR TIL220 SERIES VISIBLE-LIGHT-EMITTING DIODES

BULLETIN NO. DL-S 7412133, MAY 1974

installation instructions

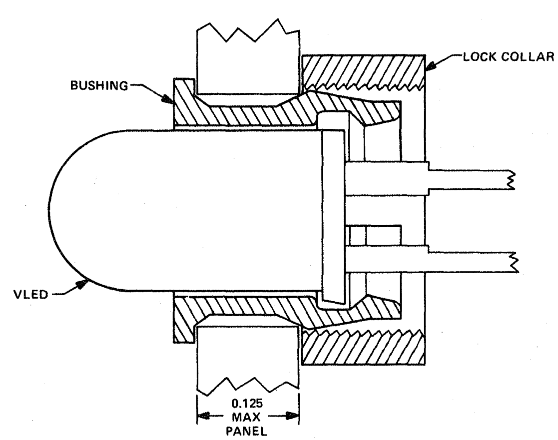
The mounting bushing for the TIL220 series can be mounted in any panel having a thickness up to 0.125 inch. To mount the bushing, drill a 17/64 (0.265)-inch-diameter hole and remove the extruded burr. Insert the bushing through the front of the panel. While holding the bushing in place, insert the VLED from the rear of the panel until the VLED snaps into place. The orientation of the flat side of the VLED, which denotes the cathode lead, must be noted prior to insertion. After the VLED is seated with its mounting flange snapped in the slot, push the lock collar over the rear side of the bushing until seated flush with the panel.

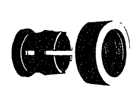
mechanical data



ALL DIMENSIONS ARE IN INCHES AND ARE NOMINAL UNLESS OTHERWISE NOTED

TYPICAL INSTALLATION





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TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES TIL261 THRU TIL270
GALLIUM ARSENIDE PHOSPHIDE VISIBLE LIGHT SOURCES

BULLETIN NO. DL-S 7412228, NOVEMBER 1974

DESIGNED TO EMIT VISIBLE RED LIGHT WHEN FORWARD BIASED

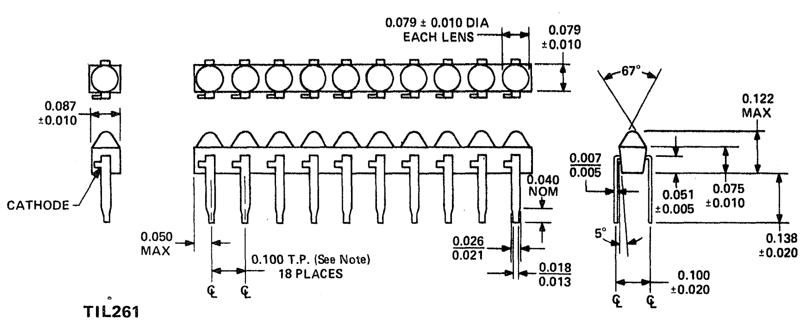
- **Recommended for Applications in Visual Indicators, Alphanumeric Displays, and No/Yes Instrumentations**
- **Single Element or Arrays from 2 to 10 Elements**
- **Center-to-Center Spacing of 0.100 Inch**

TYPE NUMBER	TIL261	TIL262	TIL263	TIL264	TIL265	TIL266	TIL267	TIL268	TIL269	TIL270
NUMBER OF ELEMENTS	1	2	3	4	5	6	7	8	9	10

7

mechanical data

Each device has a red molded filled epoxy body with silver-plated leads.

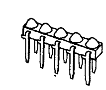


TIL261 SINGLE ELEMENT TOP AND SIDE VIEWS

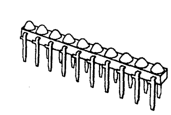
TIL270 10-ELEMENT ARRAY TOP AND SIDE VIEWS

TIL261–TIL270 END VIEW

TIL261



TIL265



TIL270

NOTE: Each pin centerline is located within 0.010 of its true longitudinal position.

All dimensions are in inches unless otherwise noted.

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature . . . . 3 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1) . . . . 40 mA
Operating Free-Air Temperature Range . . . . −40°C to 80°C
Storage Temperature Range . . . . −40°C to 100°C
Lead Temperature 1/16 Inch below Seating Plane for 3 Seconds . . . . 240°C

operating characteristics at 25°C free-air temperature

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V	Luminous Intensity	$I_F = 20$ mA	500			μcd
$\frac{I_V\ min}{I_V\ max}$	Luminous Intensity Matching Factor		0.4			
λ_p	Wavelength at Peak Emission		6300	6500	6700	Å
V_F	Static Forward Voltage			1.6	2	V
I_R	Static Reverse Current	$V_R = 3$ V		0.1	100	μA

NOTE 1: Derate linearly to 80°C free-air temperature at the rate of 0.73 mA/°C.

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BULLETIN NO. DL-S 7612233, NOVEMBER 1974–REVISED MARCH 1976

TYPES TIL271 THRU TIL280 GALLIUM PHOSPHIDE VISIBLE-LIGHT SOURCES

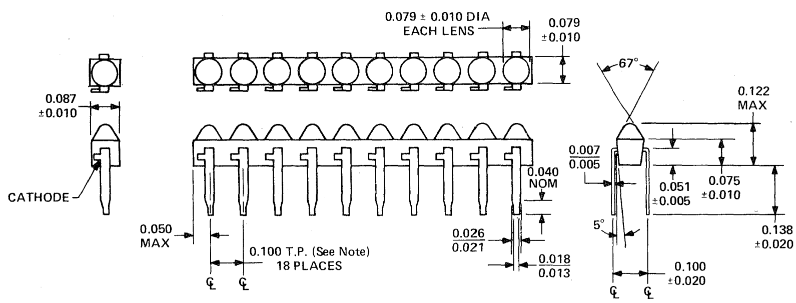
DESIGNED TO EMIT GREEN LIGHT WHEN FORWARD BIASED

- **Recommended for Applications in Visual Indicators, Alphanumeric Displays, and No/Yes Instrumentations**
- **Single Element or Arrays from 2 to 10 Elements**
- **Center-to-Center Spacing of 0.100 Inch**

TYPE NUMBER	TIL271	TIL272	TIL273	TIL274	TIL275	TIL276	TIL277	TIL278	TIL279	TIL280
NUMBER OF ELEMENTS	1	2	3	4	5	6	7	8	9	10

mechanical data

Each device has a green molded filled epoxy body with silver-plated leads.



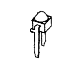
TIL271 SINGLE ELEMENT TOP AND SIDE VIEWS

TIL280 10-ELEMENT ARRAY TOP AND SIDE VIEWS

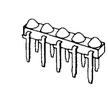
TIL271–TIL280 END VIEW

NOTE: Each pin centerline is located within 0.010 of its true longitudinal position.

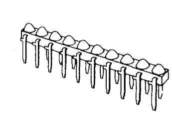
All dimensions are in inches unless otherwise noted.



TIL271



TIL275



TIL280

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature	3 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1)	30 mA
Operating Free-Air Temperature Range	−40°C to 80°C
Storage Temperature Range	−40°C to 100°C
Lead Temperature 1/16 Inch below Seating Plane for 3 Seconds	240°C

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V	Luminous Intensity	$I_F = 25$ mA	800	1500		μcd
$\frac{I_V \text{ min}}{I_V \text{ max}}$	Luminous Intensity Matching Factor		0.4			
λ_p	Wavelength at Peak Emission		5575	5650	5725	Å
V_F	Static Forward Voltage			2.7	3.5	V
I_R	Static Reverse Current	$V_R = 3$ V		0.1	100	μA

NOTE 1: Derate linearly to 80°C free-air temperature at the rate of 0.55 mA/°C.

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BULLETIN NO. DL-S 7612363, MARCH 1976

TYPES TIL281 THRU TIL290 GALLIUM ARSENIDE PHOSPHIDE ON PHOSPHIDE VISIBLE-LIGHT SOURCES

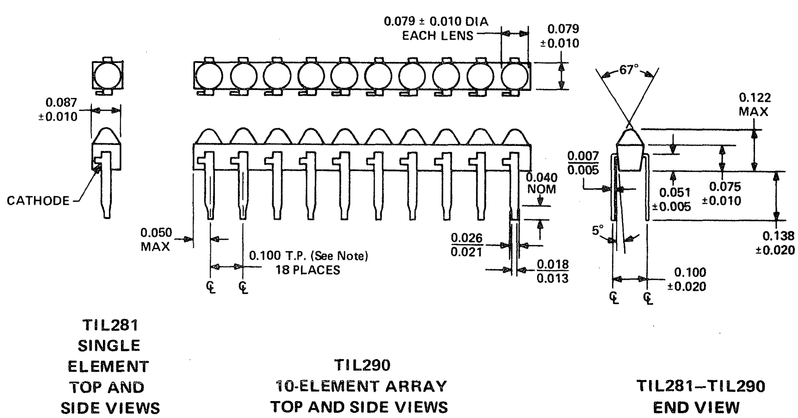
DESIGNED TO EMIT AMBER LIGHT WHEN FORWARD BIASED

- Recommended for Applications in Visual Indicators, Alphanumeric Displays, and No/Yes Instrumentations
- Single Element or Arrays from 2 to 10 Elements
- Center-to-Center Spacing of 0.100 Inch

TYPE NUMBER	TIL281	TIL282	TIL283	TIL284	TIL285	TIL286	TIL287	TIL288	TIL289	TIL290
NUMBER OF ELEMENTS	1	2	3	4	5	6	7	8	9	10

mechanical data

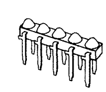
Each device has an amber molded filled epoxy body with silver-plated leads.



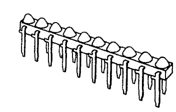
NOTE: Each pin centerline is located within 0.010 of its true longitudinal position.

All dimensions are in inches unless otherwise noted.

TIL281



TIL285



TIL290

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature . . . . 3 V
Continuous Forward Current at (or below) 25°C Free-Air Temperature (See Note 1) . . . . 30 mA
Operating Free-Air Temperature Range . . . . −40°C to 80°C
Storage Temperature Range . . . . −40°C to 100°C
Lead Temperature 1/16 Inch below Seating Plane for 3 Seconds . . . . 240°C

operating characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V	Luminous Intensity	$I_F = 25$ mA	800	1500		μcd
$\frac{I_V \text{ min}}{I_V \text{ max}}$	Luminous Intensity Matching Factor		0.4			
λ_p	Wavelength at Peak Emission		5825	5900	5975	Å
V_F	Static Forward Voltage			2.7	3.5	V
I_R	Static Reverse Current	$V_R = 3$ V		0.1	100	μA

NOTE 1: Derate linearly to 80°C free-air temperature at the rate of 0.55 mA/°C.

TENTATIVE DATA SHEET
This document provides tentative information on a new product. Texas Instruments reserves the right to change specifications for this product in any manner without notice.

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OPTOELECTRONIC FAULT INDICATOR FOR LOGIC CIRCUITS

Roland Windecker

Before the invention of the transistor, most switching functions were performed by electro-mechanical relays. Today these functions are performed largely by integrated circuits because of their versatility, speed, size, reliability, and other features. The relay did have one attractive feature, however, that the integrated circuit does not have: that is, the logic state of the relay could easily be determined by simply looking at the contact mechanism. Since semiconductor switches do not have such a built-in indicator, usually meters or oscilloscopes are used to determine the state of an output when troubleshooting is necessary. In some cases, the number of outputs to be monitored, the fact that a gate circuit does not appear at one of the circuit-board terminals, or simply that test equipment is not always readily available, may make the use of such methods impractical. It is the purpose of this application report to suggest the use of visible-light-emitting diodes (VLED's) as indicators in such cases, and to provide information that should be helpful in their application.

VLED CHARACTERISTICS

The VLED is a diode that emits visible light when forward biased. A single-crystal compound of gallium, arsenic, and phosphorous is used for the semiconductor element, and the color of the emitted light (red, 6500 Å) is obtained by controlling the phosphorous concentration. Data sheets describing TI VLED devices are available and give most of the information of interest to the design engineer planning to employ the diode as a fault indicator. One parameter that is particularly significant for this application is the relationship between forward current and emitted light. This relationship is nearly linear, but since the eye views light level in a logarithmic way, the intensity is usually plotted on a logarithmic scale as shown in Figure 1. In this graph, the light level is normalized so the information given in Table 1 is included as a rough guide for selecting current needed for a particular application.

Another point of interest is that the emitting wafer appears larger to the eye than its actual dimensions, which are about 0.01 X 0.01 inch. This effect is due in part to the lens used in the package, but is also due to an illusion that occurs because of the brilliance of the small spot.

Table 1. Relative Light Intensity Versus Current

Forward Current (mA)	Diode Light Intensity in Normal Room Lighting
0.4	Light is definitely visible.
1.0	Light is easily seen.
5.0	Light is sufficient to attract the attention of a casual observer.
10.0	Light is easily seen from a distance of twenty feet.

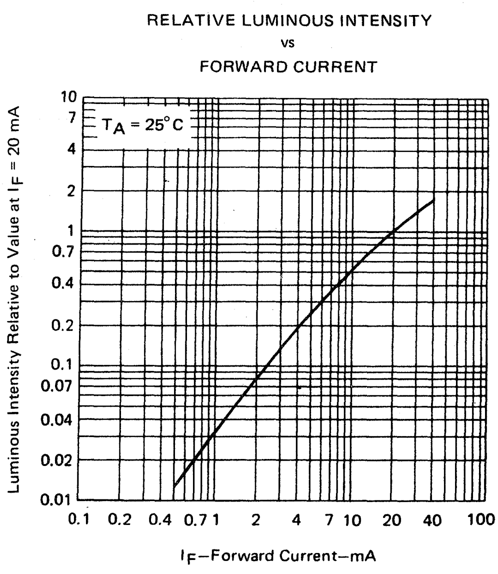

FIGURE 1. Luminous Intensity Versus Forward Current for a Typical TI VLED (TIL209A)

APPLICATIONS

The output of any integrated circuit in a computer or control system is a possible application for the VLED as a fault indicator. Obviously, only a limited number of these outputs need to be monitored, and the engineer designing maintainability into the system has the responsibility for deciding where the use of the indicator would be most effective. Outputs that normally cycle between high and low logic levels are prime candidates for this type of indicator. A VLED powered by the output of a flip-flop for example, can be adjusted to glow dimly during normal operation. When a fault occurs causing the output to be held high or low, the VLED will either glow more brightly or be off altogether, thereby revealing the state of the output. Similarly, a VLED powered by the output of a shift register can be used to indicate if the information is circulating normally (medium light intensity), is locked high (no light), or is locked low (full brilliance).

The use of the VLED to monitor command signals in computer or control systems is another possible application. The strobe signal from a keyboard or tape reader, for example, can be monitored by using a VLED at the output gate. Similarly, command signals used to control the flow of information between pieces of equipment can be monitored so that when trouble occurs, the fault can be isolated quickly.

In addition to computer and control system applications, VLED's can be powered directly by integrated-circuit outputs for other purposes, such as training personnel to understand logic circuits, helping the design engineer develop complex logic circuits, and reading outputs of test consoles used to diagnose and trouble shoot computer systems.

TYPICAL CIRCUITS

TTL Integrated Circuits

The circuit shown in Figure 2 can be used to monitor the output of a 54/74 TTL integrated circuit or similar logic circuits. Table 2 gives values for the limiting resistor required and includes the fan-out that must not be exceeded when the added lamp load is taken into account. This chart is based on the assumption that the TTL gate can sink 16 mA and that 1.6 mA is required by each of the driven TTL gates. If a high-current buffer (SN7440) is used as the TTL gate, 48 mA is available, and the expanded chart given in Table 3 is applicable. When very large currents are required for the indicator, a gate-transistor combination such as the SN75450B can be used. The circuit shown in Figure 3 was used to monitor a gate operating at 5 kHz with a 5% duty cycle. Resistor R2 is used to limit the diode current to a safe value when the gate output is held high due to a fault condition. The bypass capacitor increases the light level above that normally seen with a 5% duty cycle.

Table 2

I_D(mA)	0.5	1	2	4	6	8	10	14
R(kΩ)	6.5	3.2	1.6	0.8	0.51	0.39	0.30	
Fan-Out	9	9	8	7	6	5	3	1

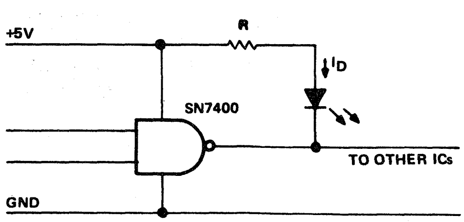

FIGURE 2. Circuit used to Monitor Gate of TTL IC

Table 3

I_D(mA)	10	15	20	25	30	40	45
R(Ω)	309	200	160	125	100	73	62
Fan-Out	33	20	17	14	11	5	1

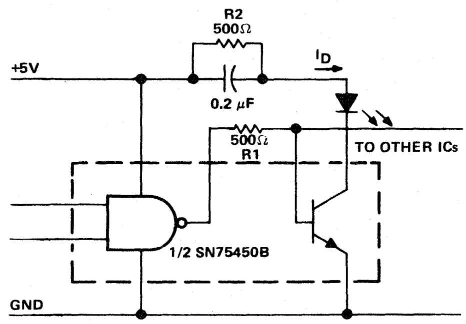

FIGURE 3. Circuit Used to Monitor Gate of a TTL IC Operating at 5 kHz with 5% Duty Cycle

The fault indicator shown in Figure 1 emits light when the output is low and is dark when the output is high. If the inverse response is required, that is, light when the output is high and no light when the output is low, the circuit shown in Figure 4 can be used. Table 4 gives corresponding series resistance and gate output voltage. Fan-out is not affected by this configuration, but care must be used in limiting the current to a level that does not reduce the output voltage below the recommended level.

DTL Integrated Circuits

The VLED can be used to indicate trouble with DTL integrated circuits as well as with TTL. Figure 5 and Table 5 illustrate the use of a VLED to monitor a 4-input NAND gate, type SN15830.

Table 4

I_D(mA)	0.3	0.5	0.75	1.0	1.5
R(kΩ)	6.9	3.9	2.5	1.7	1.3
V_{OH}(V)	3.62	3.6	3.52	3.5	3.46

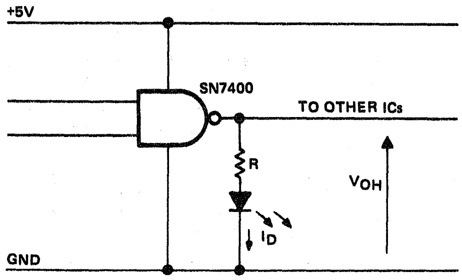

FIGURE 4. Fault Indicator Circuit That Emits Light When Output is High and is Dark When Output is Low

Table 5

I_D(mA)	0.5	1	2	4	6	8	10
R(Ω)	6700	3200	1600	800	520	380	290
Fan-Out	8	7	7	5	4	2	1

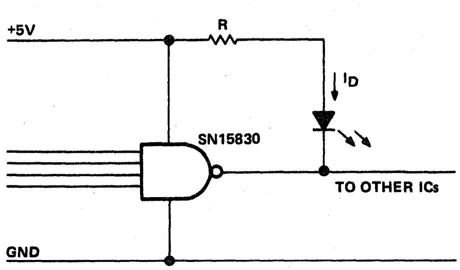

FIGURE 5. VLED Monitoring an SN15830 4-Input NAND Gate

Table 6

I_D(mA)	0.8	1.6	2.0
R1(Ω)	1400	700	500
R2(Ω)	1000	510	330

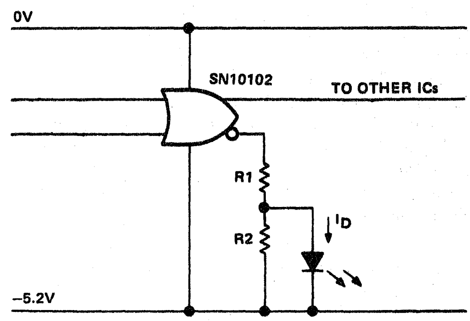

FIGURE 6. VLED Monitoring Output of SN10102 OR/NOR Gate

ECL Integrated Circuits

Since the voltage swing at the output of an ECL gate is approximately 0.8 volts (−1.7 V to −0.9 V), the application of the VLED across an active output is not recommended. Since many of the ECL gates have more than one output, it is possible to use one of these for the VLED while using the remaining outputs in the logic circuits. The VLED affects the remainder of the circuit only in that its current contributes to the power dissipation in the ECL chip. Figure 6 shows a VLED monitoring the output of an SN10102 OR/NOR gate.

ADDITIONAL APPLICATIONS

The circuits presented here are intended to suggest a variety of configurations for applying the VLED as a fault indicator and to illustrate the simplicity of such circuits when used on integrated circuit gates. If a few basic limitations are kept in mind, such as the maximum continuous current and maximum reverse breakdown, the VLED is a very easy device to apply. The reliability and long life eliminate the need to provide for frequent replacement, and its small size and low power dissipation allow the user to concentrate a large number of the indicators in a relatively small area.

7

7

Displays

8

DISPLAYS
QUICK REFERENCE GUIDE

DEVICE	TYPE OF CHARACTER(S)	CHARACTER HEIGHT (INCHES)	COLOR OF DISPLAY	PACKAGE*	REMARKS
TIL302 TIL303	7-segment	0.270	Red	14-lead dual-in-line plastic	TIL302—left decimal. TIL303—right decimal.
TIL304	Polarity and overflow unit	0.270	Red	14-lead dual-in-line plastic	Right decimal.
TIL305	5 X 7 alphanumeric	0.300	Red	14-lead dual-in-line plastic	Left decimal.
TIL306 TIL307 TIL308 TIL309	7-segment	0.270	Red	16-lead dual-in-line plastic	Logic in TIL306 and TIL307 includes decade counter, latch, current source driver, and decoder. Logic in TIL308 and TIL309 is same except decade counter not included. TIL306 and TIL308—left decimal. TIL307 and TIL309—right decimal.
TIL311	Hexadecimal	0.270	Red	14-lead dual-in-line plastic	Logic includes latch, decoder, and driver. Left and right decimals.
TIL312 TIL313	7-segment	0.300	Red	14-lead dual-in-line plastic	TIL312 has common anode, right and left decimals. TIL313 has common cathode, right decimal only.
TIL314 TIL315	7-segment	0.300	Green	14-lead dual-in-line plastic	TIL314 has common anode, right and left decimals. TIL315 has common cathode, right decimal only.
TIL316 TIL317	7-segment	0.300	Amber	14-lead dual-in-line plastic	TIL316 has common anode, right and left decimals. TIL317 has common cathode, right decimal only.
TIL321 TIL322	7-segment	0.500	Red	10-lead dual-in-line plastic	Right decimal. TIL321 is common-anode, TIL322 is common-cathode.
TIL323 TIL324	7-segment	0.500	Green	10-lead dual-in-line plastic	Right decimal. TIL323 is common-anode, TIL324 is common-cathode.
TIL325 TIL326	7-segment	0.500	Amber	10-lead dual-in-line plastic	Right decimal. TIL325 is common-anode, TIL326 is common-cathode.
TIL327	Polarity and overflow unit	0.300	Red	14-lead dual-in-line plastic	Left decimal.
TIL328	Polarity and overflow unit	0.300	Green	14-lead dual-in-line plastic	Left decimal.
TIL329	Polarity and overflow unit	0.300	Amber	14-lead dual-in-line plastic	Left decimal.
TIL330	Polarity and overflow unit	0.500	Red	10-lead dual-in-line plastic	Right decimal.
TIL331	Polarity and overflow unit	0.500	Green	10-lead dual-in-line plastic	Right decimal.
TIL332	Polarity and overflow unit	0.500	Amber	10-lead dual-in-line plastic	Right decimal.
TIL360	7-segment	0.100	Red	16-lead dual-in-line plastic	6-digit display, each digit having right decimal.
TIL361	7-segment	0.500	Red	1.4 x 1.0 pcb	2-digit display, molded in plastic, mounted on 9-tab printed-circuit board.
TIL362	7-segment	0.500	Green	1.4 x 1.0 pcb	Same as TIL361 except for color.
TIL363	7-segment	0.500	Amber	1.4 x 1.0 pcb	Same as TIL361 except for color

*Dimensions of printed-circuit boards and substrates are in inches.

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TEXAS INSTRUMENTS
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DISPLAYS
QUICK REFERENCE GUIDE (Continued)

DEVICE	TYPE OF CHARACTER(S)	CHARACTER HEIGHT (INCHES)	COLOR OF DISPLAY	PACKAGE*	REMARKS
TIL364	7-segment	0.500	Red	3.2 x 1.03 pcb	4-digit 12-hour clock display with alarm and PM indicators, molded in plastic, mounted on 16-tab printed-circuit board.
TIL365	7-segment	0.500	Green	3.2 x 1.03 pcb	Same as TIL364 except for color.
TIL366	7-segment	0.500	Amber	3.2 x 1.03 pcb	Same as TIL364 except for color.
TIL367	7-segment	0.500	Red	3.2 x 1.03 pcb	Same as TIL364 except without alarm indicator.
TIL368	7-segment	0.500	Green	3.2 x 1.03 pcb	Same as TIL365 except without alarm indicator.
TIL369	7-segment	0.500	Amber	3.2 x 1.03 pcb	Same as TIL366 except without alarm indicator.
TIL370	7-segment	0.500	Red	3.2 x 1.03 pcb	4-digit 24-hour clock display with alarm indicator molded in plastic, mounted on 16-tab printed-circuit board.
TIL371	7-segment	0.500	Green	3.2 x 1.03 pcb	Same as TIL370 except for color.
TIL372	7-segment	0.500	Amber	3.2 x 1.03 pcb	Same as TIL370 except for color.
TIL373	7-segment	0.500	Red	3.2 x 1.03 pcb	Same as TIL370 except without alarm indicator.
TIL374	7-segment	0.500	Green	3.2 x 1.03 pcb	Same as TIL371 except without alarm indicator.
TIL375	7-segment	0.500	Amber	3.2 x 1.03 pcb	Same as TIL372 except without alarm indicator.
TIL379-12	7-segment	0.106†	Red	2.36 x 0.72 pcb	12-digit calculator numeric display with lens mounted on a 20-tab printed circuit board.
TIL380-8	7-segment	0.110†	Red	2.375 x 0.72 pcb	8-digit calculator numeric display with lens mounted on an 18-tab printed circuit board.
TIL380-9	7-segment	0.110†	Red	2.375 x 0.72 pcb	9-digit display, otherwise same as TIL380-8.
TIL382	7-segment	0.100	Red	0.75 x 0.21 sub	4-digit plus colon watch display on a 20-pad substrate.
TIL383	9-, 7-segment	0.100	Red	0.75 x 0.21 sub	4-digit plus colon watch display on a 20-pad substrate.
TIL384	7-segment	0.116	Red	0.75 x 0.21 sub	4-digit plus colon watch display on a 20-pad substrate.
TIL385	9-, 7-segment	0.116	Red	0.75 x 0.21 sub	4-digit plus colon watch display on a 20-pad substrate.
TIL392-6	7-segment	0.102†	Red	2.375 x 0.72 pcb	6-digit calculator numeric display with lens mounted on an 18-tab printed circuit board.
TIL392-8	7-segment	0.102†	Red	2.375 x 0.72 pcb	8-digit display, otherwise same as TIL392-6.
TIL392-9	7-segment	0.102†	Red	2.375 x 0.72 pcb	9-digit display, otherwise same as TIL392-6.
TIL393-6	7-segment	0.102†	Red	2.0 x 0.72 pcb	6-digit calculator numeric display, with lens mounted on an 18-tab printed circuit board.
TIL393-8	7-segment	0.102†	Red	2.0 x 0.72 pcb	8-digit display, otherwise same as TIL393-6.
TIL393-9	7-segment	0.102†	Red	2.0 x 0.72 pcb	9-digit display, otherwise same as TIL393-6.
TIL394-8	7-segment	0.110†	Red	2.0 x 0.72 pcb	8-digit calculator numeric display with lens mounted on an 18-tab printed circuit board.
TIL394-9	7-segment	0.110†	Red	2.0 x 0.72 pcb	9-digit display, otherwise same as TIL394-8.
TIL396	9-, 7-segment	0.104†	Red	0.75 x 0.21 sub	4-digit plus colon watch display on a 20-tab substrate.
TIL397	9-, 7-segment	0.104†	Red	0.75 x 0.21 sub	4-digit watch display on a 20-tab substrate.
TIL398	7-segment	0.104†	Red	0.75 x 0.21 sub	4-digit plus colon watch display on a 20-tab substrate.
TIL399	7-segment	0.104†	Red	0.75 x 0.21 sub	4-digit watch display on a 20-tab substrate.

*Dimensions of printed-circuit boards and substrates are in inches.
†Height of magnified character.

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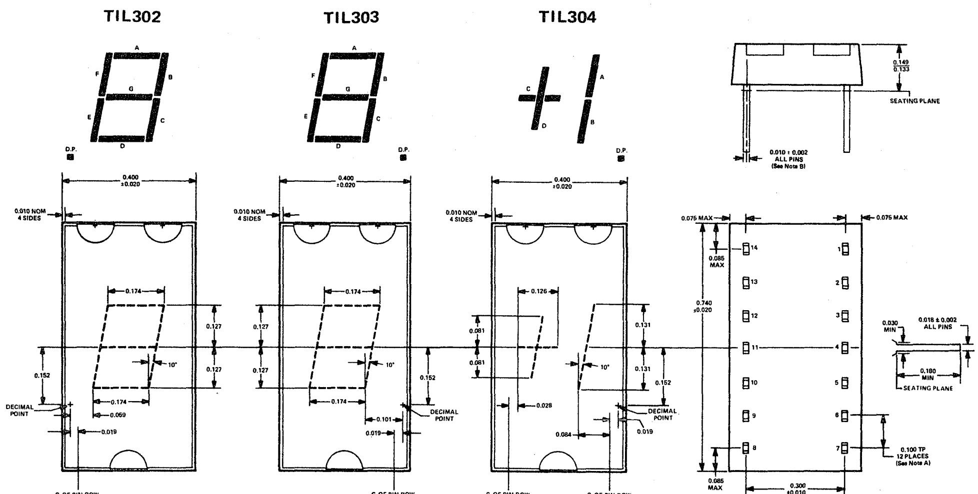
BULLETIN NO. DL-S 7611470, APRIL 1971–REVISED MARCH 1976

SOLID-STATE VISIBLE DISPLAY FAMILY WITH RED TRANSPARENT PLASTIC ENCAPSULATION

- 0.270" High Characters
- Sign, Overflow, Left or Right Decimal Capability
- High Luminous Intensity
- Wide Viewing Angle
- Low Power Requirements
- Compatible with Most TTL and DTL Circuits
- Each Unit Visually Checked for Uniformity of Elements

mechanical data

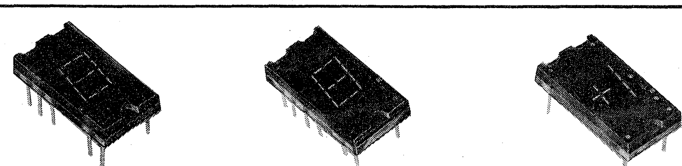
The display chips are mounted on a header and this assembly is then cast within a red, electrically nonconductive, transparent plastic compound. Multiple displays may be mounted on 0.450-inch centers.



TIL302	TIL303	TIL304
PIN 1 – CATHODE A	PIN 1 – CATHODE A	PIN 1 – ANODE C, D
PIN 2 – CATHODE F	PIN 2 – ANODE A, F	PIN 2 – OMITTED
PIN 3 – ANODE E, F, G, & DECIMAL	PIN 3 – CATHODE F	PIN 3 – OMITTED
PIN 4 – OMITTED	PIN 4 – CATHODE G	PIN 4 – OMITTED
PIN 5 – OMITTED	PIN 5 – OMITTED	PIN 5 – OMITTED
PIN 6 – CATHODE DECIMAL	PIN 6 – CATHODE E	PIN 6 – OMITTED
PIN 7 – CATHODE E	PIN 7 – ANODE D, E, DECIMAL	PIN 7 – CATHODE D
PIN 8 – CATHODE D	PIN 8 – CATHODE D	PIN 8 – CATHODE C
PIN 9 – ANODE C, D	PIN 9 – CATHODE C	PIN 9 – CATHODE DECIMAL
PIN 10 – CATHODE C	PIN 10 – CATHODE DECIMAL	PIN 10 – CATHODE B
PIN 11 – CATHODE G	PIN 11 – OMITTED	PIN 11 – CATHODE A
PIN 12 – OMITTED	PIN 12 – OMITTED	PIN 12 – OMITTED
PIN 13 – CATHODE B	PIN 13 – ANODE B, C, G	PIN 13 – OMITTED
PIN 14 – ANODE A, B	PIN 14 – CATHODE B	PIN 14 – ANODE A, B, DECIMAL

END AND BOTTOM VIEWS AND TERMINAL DETAIL FOR ALL THREE TYPES

NOTES:
A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within ±0.010 of its true longitudinal position relative to pins 4 and 11.
B. Lead dimensions are not controlled above the seating plane.
C. Centerlines of character segments and decimal points are shown as dashed lines. Associated dimensions are nominal.
D. All dimensions are in inches unless otherwise specified.



TIL302 TIL303 TIL304

TEXAS INSTRUMENTS
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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Reverse Voltage at 25°C Free-Air Temperature:
- Each Segment . . . . 6 V
- Decimal Point . . . . 3 V

Peak Forward Current, Each Segment or Decimal Point (See Note 1) . . . . 200 mA

Continuous Forward Current:
- Each Segment or Decimal Point . . . . 30 mA
- Total for TIL302, TIL303 . . . . 240 mA
- Total for TIL304 . . . . 150 mA

Operating Free-Air Temperature Range . . . . 0°C to 70°C
Storage Temperature Range . . . . −25°C to 85°C

NOTE 1: This value applies for PRR ⩾ 60 Hz, duty cycle ⩽ 10%.

operating characteristics of each segment at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TIL302, TIL303			TIL304			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
I_V	Luminous Intensity (See Note 2)	I_F = 20 mA	100	275		100	275		μcd
λ_p	Wavelength at Peak Emission		640	660	680	640	660	680	nm
$\Delta\lambda$	Spectral Bandwidth			20			20		nm
V_F	Static Forward Voltage		3	3.4	3.8	3	3.4	3.8	V
α_{VF}	Average Temperature Coefficient of Static Forward Voltage	I_F = 20 mA, T_A = 0°C to 70°C		−2.7			−2.7		mV/°C
I_R	Static Reverse Current	V_R = 6 V			100			100	μA
C	Anode-to-Cathode Capacitance	V_R = 0, f = 1 MHz		85			85		pF

operating characteristics of decimal point at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V	Luminous Intensity (See Note 2)	I_F = 20 mA	40	110		μcd
λ_p	Wavelength at Peak Emission		645	665	685	nm
$\Delta\lambda$	Spectral Bandwidth			20		nm
V_F	Static Forward Voltage		1.5	1.65	2	V
α_{VF}	Average Temperature Coefficient of Static Forward Voltage	I_F = 20 mA, T_A = 0°C to 70°C		−1.4		mV/°C
I_R	Static Reverse Current	V_R = 3 V			100	μA
C	Anode-to-Cathode Capacitance	V_R = 0, f = 1 MHz		120		pF

NOTE 2: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

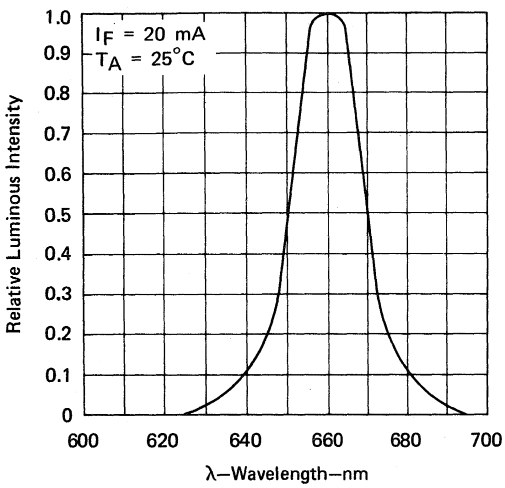

FIGURE 1

RELATIVE LUMINOUS INTENSITY
vs
FREE-AIR TEMPERATURE

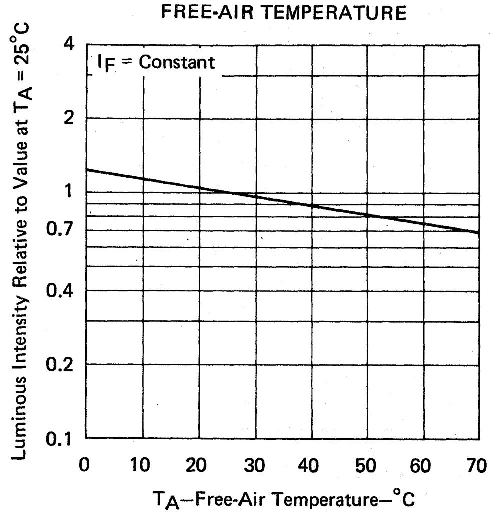

FIGURE 2

RELATIVE LUMINOUS INTENSITY
vs
FORWARD CURRENT

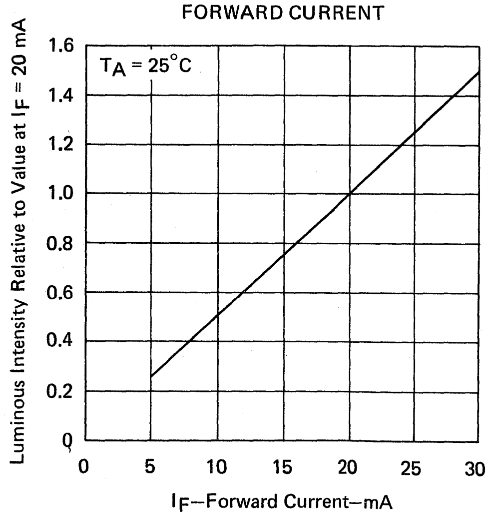

FIGURE 3

FORWARD CONDUCTION CHARACTERISTICS

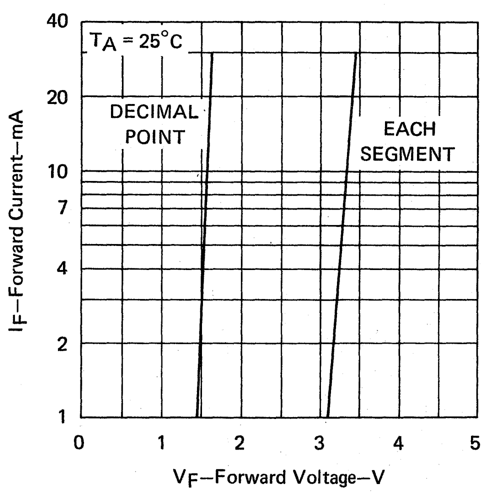

FIGURE 4

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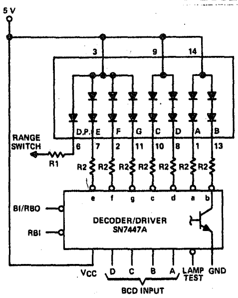
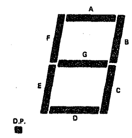
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

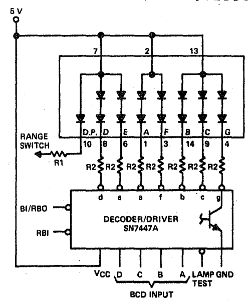
TYPICAL APPLICATION DATA

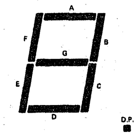
TIL302





TIL303





NOTES: A. R1 and R2 are selected for desired brightness.

B. SN74L47 may be used in place of SN7447A in applications where segment forward current will not exceed 20 mA.

FUNCTION TABLE
SN7447A

DECIMAL OR FUNCTION	INPUTS						BI/RBO†	SEGMENTS							NOTE
	LT	RBI	D	C	B	A		a	b	c	d	e	f	g	
0	H	H	L	L	L	L	H	ON	ON	ON	ON	ON	ON	OFF	1
1	H	X	L	L	L	H	H	OFF	ON	ON	OFF	OFF	OFF	OFF	1
2	H	X	L	L	H	L	H	ON	ON	OFF	ON	ON	OFF	ON	1
3	H	X	L	L	H	H	H	ON	ON	ON	ON	OFF	OFF	ON	1
4	H	X	L	H	L	L	H	OFF	ON	ON	OFF	OFF	ON	ON	1
5	H	X	L	H	L	H	H	ON	OFF	ON	ON	OFF	ON	ON	1
6	H	X	L	H	H	L	H	OFF	OFF	ON	ON	ON	ON	ON	1
7	H	X	L	H	H	H	H	ON	ON	ON	OFF	OFF	OFF	OFF	1
8	H	X	H	L	L	L	H	ON	ON	ON	ON	ON	ON	ON	1
9	H	X	H	L	L	H	H	ON	ON	ON	OFF	OFF	ON	ON	1
10	H	X	H	L	H	L	H	OFF	OFF	OFF	ON	ON	OFF	ON	1
11	H	X	H	L	H	H	H	OFF	OFF	ON	ON	OFF	OFF	ON	1
12	H	X	H	H	L	L	H	OFF	ON	OFF	OFF	OFF	ON	ON	1
13	H	X	H	H	L	H	H	ON	OFF	OFF	ON	OFF	ON	ON	1
14	H	X	H	H	H	L	H	OFF	OFF	OFF	ON	ON	ON	ON	1
15	H	X	H	H	H	H	H	OFF	OFF	OFF	OFF	OFF	OFF	OFF	1
BI	X	X	X	X	X	X	L	OFF	OFF	OFF	OFF	OFF	OFF	OFF	2
RBI	H	L	L	L	L	L	L	OFF	OFF	OFF	OFF	OFF	OFF	OFF	3
LT	L	X	X	X	X	X	H	ON	ON	ON	ON	ON	ON	ON	4

H = high level (logic 1 in positive logic), L = low level (logic 0 in positive logic), X = irrelevant.

†BI/RBO is wire-AND logic serving as blanking input (BI) and/or ripple-blanking output (RBO).

NOTES: 1. The blanking input (BI) must be open or held at a high logic level when output functions 0 through 15 are desired. The ripple-blanking input (RBI) must be open or high if blanking of a decimal zero is not desired.

2. When a low logic level is applied directly to the blanking input (BI), all segment outputs are off regardless of any other input.

3. When the ripple-blanking input (RBI) and inputs A, B, C, and D are at a low logic level with the lamp test input high, all segment outputs are off and the ripple-blanking output (RBO) of the decoder goes to a low level (response condition).

4. When the blanking input/ripple blanking output (BI/RBO) is open or held high and a low is applied to the lamp-test input, all segments are illuminated.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

NUMERICAL DESIGNATIONS—RESULTANT DISPLAYS

RECOMMENDED DECODE/DRIVE WITH BCD INPUTS

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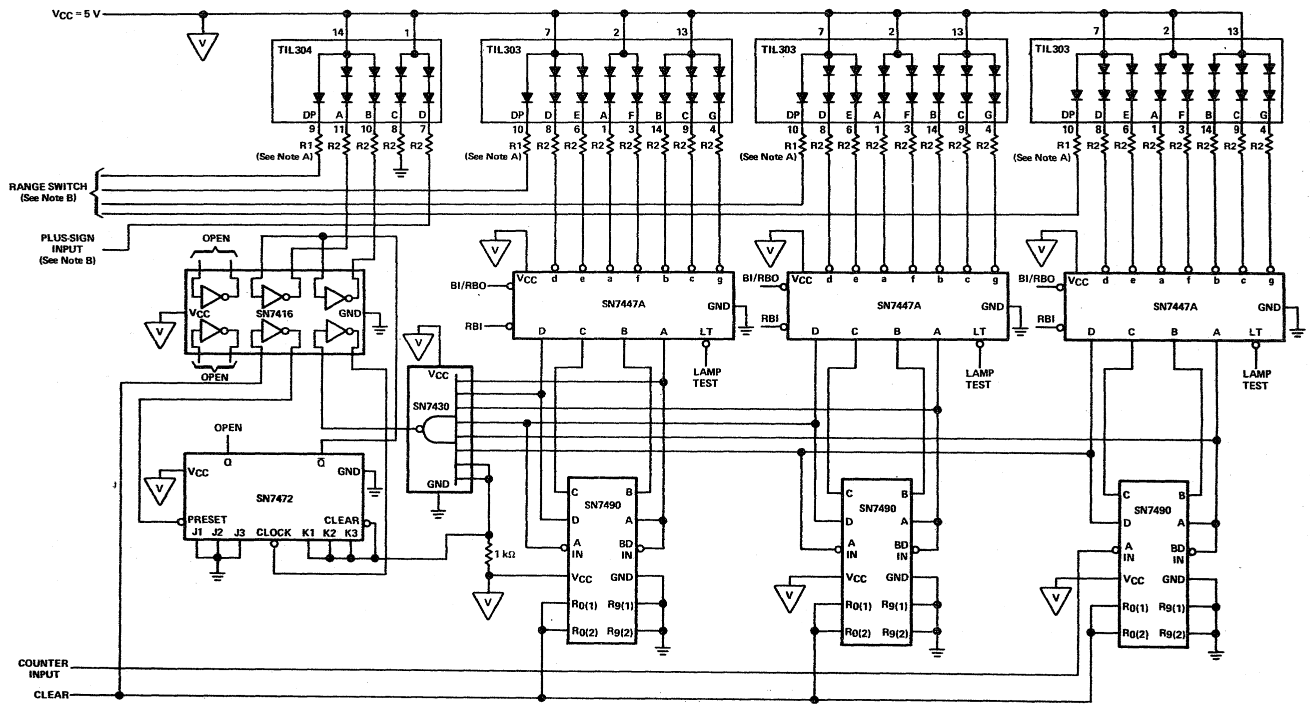
TYPICAL APPLICATION DATA

The TIL303 and TIL304 are used in this application to make a three-digit display with sign, which is capable of 100% overrange ("1" plus three digits). The decimal point is located via an external range switch. The clear function will blank the overflow digit and reset the three digits to zero. Following resetting, input pulses will be counted, decoded, and displayed.



NOTES: A. R1 and R2 are selected for desired brightness.
B. Grounding of any of these lines will illuminate the associated function.

▽ . . . V_{CC} bus

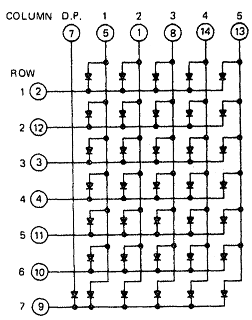
BULLETIN NO. DL-S 7611495, MAY 1971—REVISED MARCH 1976

SOLID-STATE VISIBLE DISPLAY WITH RED TRANSPARENT PLASTIC ENCAPSULATION

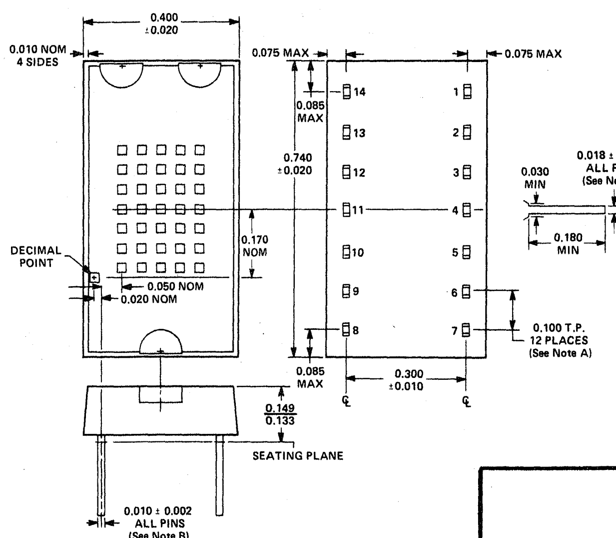
- 0.300-Inch-High Character
- High Luminous Intensity
- Low Power Requirements
- Wide Viewing Angle
- 5 X 7 Array with X-Y Select and Decimal
- Compatible with USASCII and EBCDIC Codes

mechanical data

The display chips are mounted on a header and this assembly is then cast within a red, electrically nonconductive, transparent plastic compound. Multiple displays may be mounted on 0.450-inch centers.

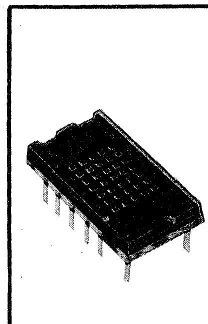


TOP VIEW ORIENTATION



PIN 1 COLUMN 2
PIN 2 ROW 1
PIN 3 ROW 3
PIN 4 ROW 4
PIN 5 COLUMN 1
PIN 6 OMITTED
PIN 7 DECIMAL ANODE
PIN 8 COLUMN 3
PIN 9 ROW 7 AND DECIMAL CATHODE
PIN 10 ROW 6
PIN 11 ROW 5
PIN 12 ROW 2
PIN 13 COLUMN 5
PIN 14 COLUMN 4

At the option of Texas Instruments, round leads having a diameter of 0.018 ± 0.002 may be substituted for the lead frame illustrated. All other dimensions remain the same.



NOTES:
A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within ±0.010 of its true longitudinal position relative to pins 4 and 11.
B. Lead dimensions are not controlled above the seating plane.
C. Vertical and horizontal spacing between centerlines of rows and columns is nominally 0.050.
D. All dimensions are in inches.

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TYPE TIL305
5 X 7 ALPHANUMERIC DISPLAY

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Reverse Voltage at 25°C Free-Air Temperature	3 V
Peak Forward Current, Each Diode	100 mA
Average Forward Current (See Note 1):	
Each Diode	10 mA
Total	200 mA
Operating Free-Air Temperature Range	0° to 70°C
Storage Temperature Range	−25°C to 85°C

operating characteristics of each diode at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_v	Luminous Intensity (See Note 2)	I_F = 10 mA	40	110		µcd
λ_p	Wavelength at Peak Emission		640	660	680	nm
$\Delta\lambda$	Spectral Bandwidth			20		nm
V_F	Static Forward Voltage		1.5	1.65	2	V
α_{VF}	Average Temperature Coefficient of Static Forward Voltage	I_F = 10 mA, T_A = 0°C to 70°C		−1.4		mV/°C
I_R	Static Reverse Current	V_R = 3 V		10		µA
C	Anode-to-Cathode Capacitance	V_R = 0, f = 1 MHz		80		pF

NOTES: 1. This average value applies for any 1-ms period.
2. Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

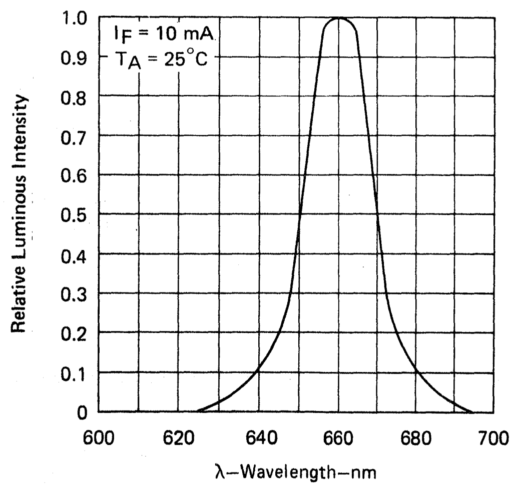

FIGURE 1

RELATIVE LUMINOUS INTENSITY vs FREE-AIR TEMPERATURE

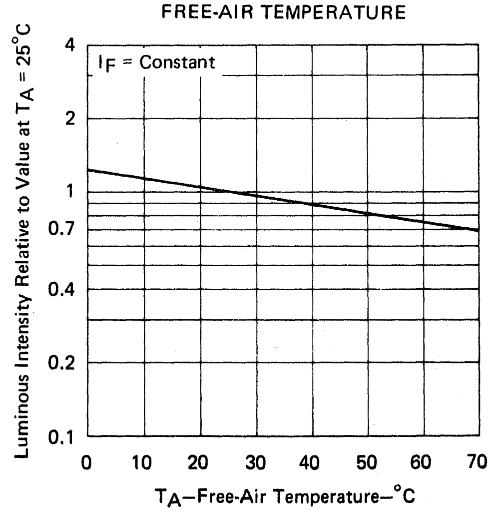

FIGURE 2

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TYPICAL CHARACTERISTICS

RELATIVE LUMINOUS INTENSITY
vs
FORWARD CURRENT

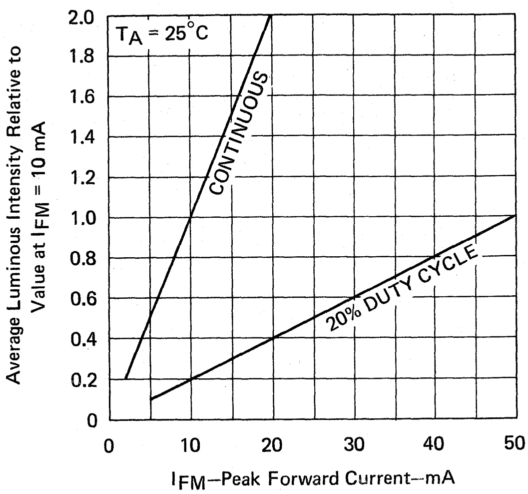

FIGURE 3

FORWARD CONDUCTION CHARACTERISTICS

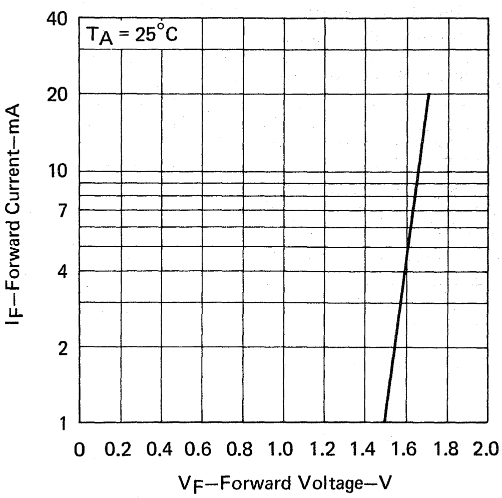

FIGURE 4

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TYPICAL APPLICATION DATA

The TIL305 is used as a single character display in the application illustrated in Figure 5. The character displayed is a function of the logic input lines 1 through 7 and the blanking input. A low-logic-level voltage applied to the blanking input will inhibit the display.

The five columns of the TIL305 are scanned with a 20% duty cycle. The sequencing is controlled by the unijunction transistor oscillator, SN7496 shift register, and one of the SN7416 hex inverter/buffer drivers that are used to invert and feed the outputs back to the serial input to form a ring counter.

The outputs of the ring counter are used to drive the column drivers (A5T2907's) and the column select inputs of the read-only memory after being inverted through another SN7416.

The logic inputs 1 through 7 are inverted with another SN7416 to make the inputs compatible with positive logic and Series 54/74 levels.

If the coding at the inputs 1 through 7 is USASCII, a TMS4103JC or TMS4103NC read-only memory may be used to display the alpha-numeric characters per Figure 6. If the coding is EBCDIC, then a TMS4179JC or TMS4179NC will display the alpha-numeric characters per Figure 7. The TMS4103 and TMS4179 are pin-for-pin replacements in this circuit. Other codes may be used with a custom TMS4100 read-only memory.

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TYPICAL APPLICATION DATA

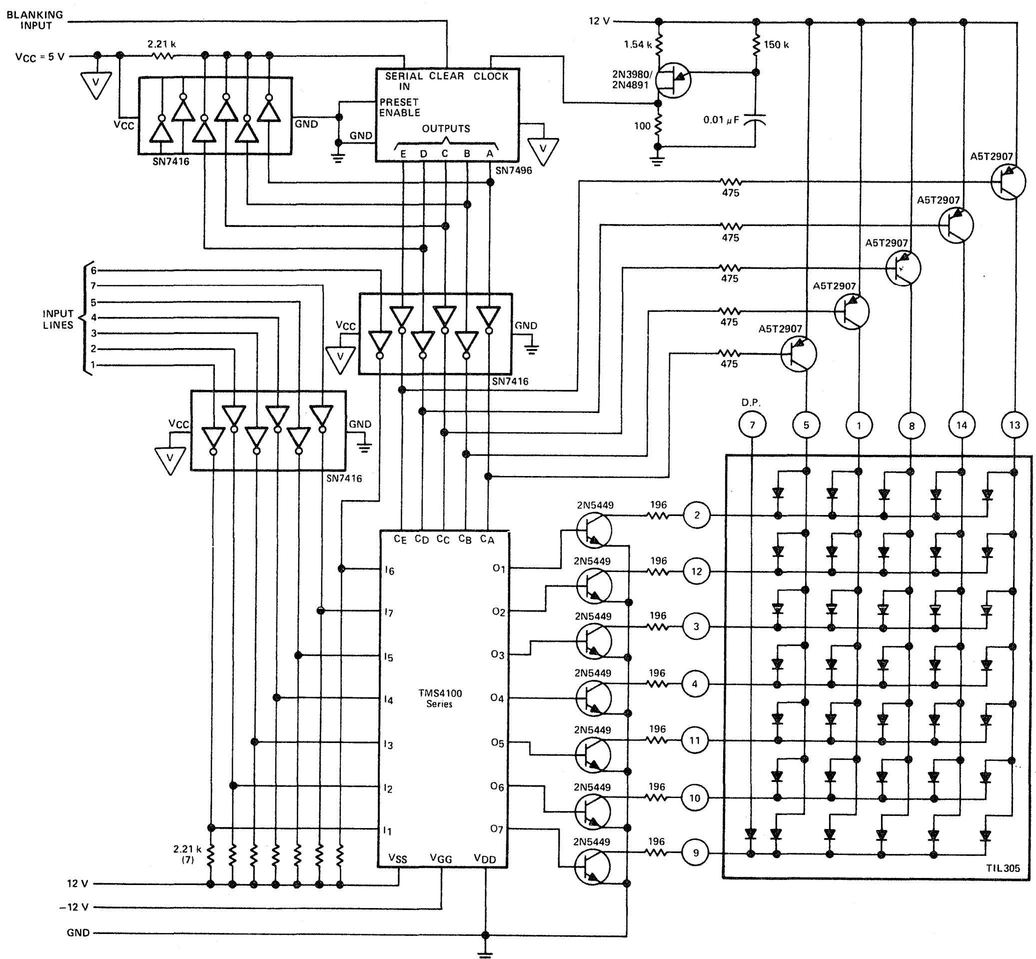

FIGURE 5

Resistor values are in ohms.

▽ . . . V_{CC} bus.

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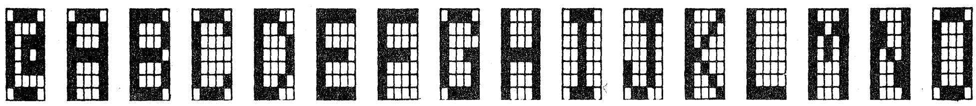
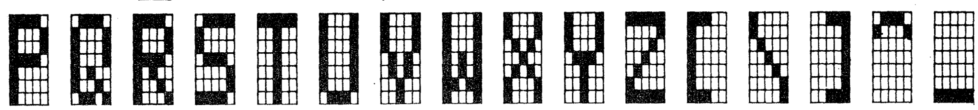
TYPICAL APPLICATION DATA

RESULTANT DISPLAYS USING TMS4103JC OR TMS4103NC WITH USASCII CODED INPUTS

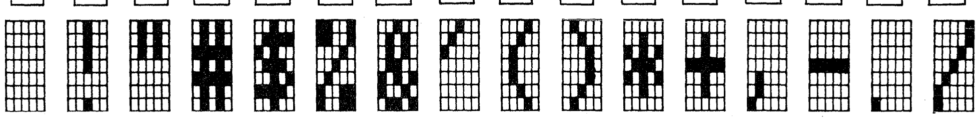
1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



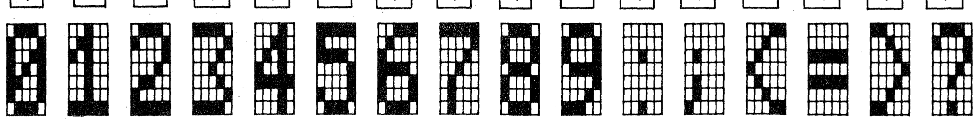
1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



positive logic: 1 = H = 2 V to 5.5 V
0 = L = 0 V to 0.8 V

FIGURE 6

TEXAS INSTRUMENTS
INCORPORATED
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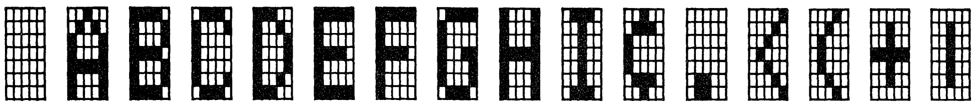
TYPICAL APPLICATION DATA

RESULTANT DISPLAYS USING TMS4179JC OR TMS4179NC WITH EBCDIC CODED INPUTS

1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
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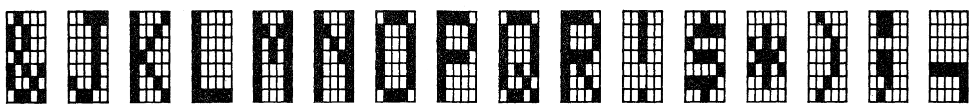
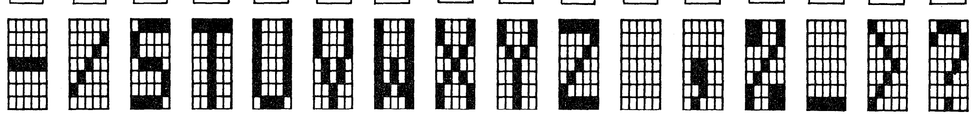
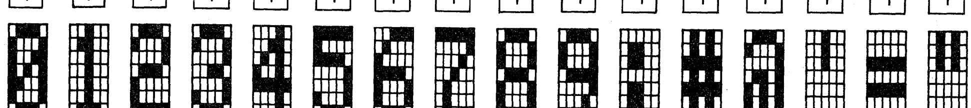
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



positive logic: 1 = H = 2 V to 5.5 V
0 = L = 0 V to 0.8 V

FIGURE 7

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TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

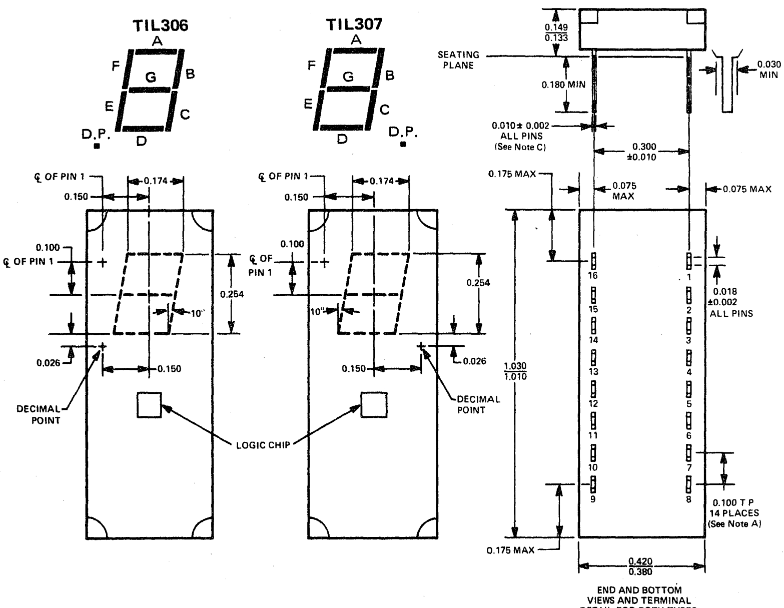
BULLETIN NO. DL-S 7611551, MARCH 1972—REVISED MARCH 1976

SOLID-STATE VISIBLE DISPLAYS WITH INTEGRAL TTL MSI CIRCUIT CHIP FOR USE IN ALL SYSTEMS WHERE THE DATA TO BE DISPLAYED IS THE PULSE COUNT

- **0.270-Inch-High Character**
- **High Luminous Intensity**
- **TIL306 Has Left Decimal**
- **TIL307 Has Right Decimal**
- **Easy System Interface**
- **Wide Viewing Angle**
- **Internal TTL MSI Chip and Counter, Latch, Decoder, and Driver**
- **Constant-Current Drive for Light-Emitting Diodes**

mechanical data

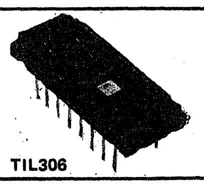
The display chips and TTL MSI chip are mounted on a header and this assembly is then cast within a red, electrically nonconductive, transparent plastic compound. Multiple displays may be mounted on 0.450-inch centers.

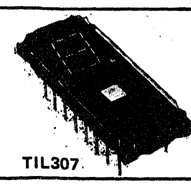


PIN ASSIGNMENTS FOR BOTH TYPES

PIN 1	LATCH OUTPUT Q_B (BINARY WEIGHT 2)
PIN 2	LATCH OUTPUT Q_C (BINARY WEIGHT 4)
PIN 3	LATCH OUTPUT Q_D (BINARY WEIGHT 8)
PIN 4	LATCH OUTPUT Q_A (BINARY WEIGHT 1)
PIN 5	LATCH STROBE INPUT
PIN 6	RIPPLE-BLANKING INPUT
PIN 7	MAXIMUM-COUNT OUTPUT
PIN 8	GROUND
PIN 9	PARALLEL COUNT ENABLE INPUT
PIN 10	SERIAL COUNT ENABLE INPUT
PIN 11	RIPPLE-BLANKING OUTPUT
PIN 12	CLEAR INPUT
PIN 13	DECIMAL POINT INPUT
PIN 14	BLANKING INPUT
PIN 15	CLOCK INPUT
PIN 16	SUPPLY VOLTAGE, V_{CC}

NOTES:
A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within 0.010 of its true longitudinal position relative to pins 1 and 16.
B. Centerlines of character segments and decimal points are shown as dashed lines. Associated dimensions are nominal.
C. Lead dimensions are not controlled above the seating plane.
D. All dimensions are in inches unless otherwise specified.


TIL306


TIL307

8

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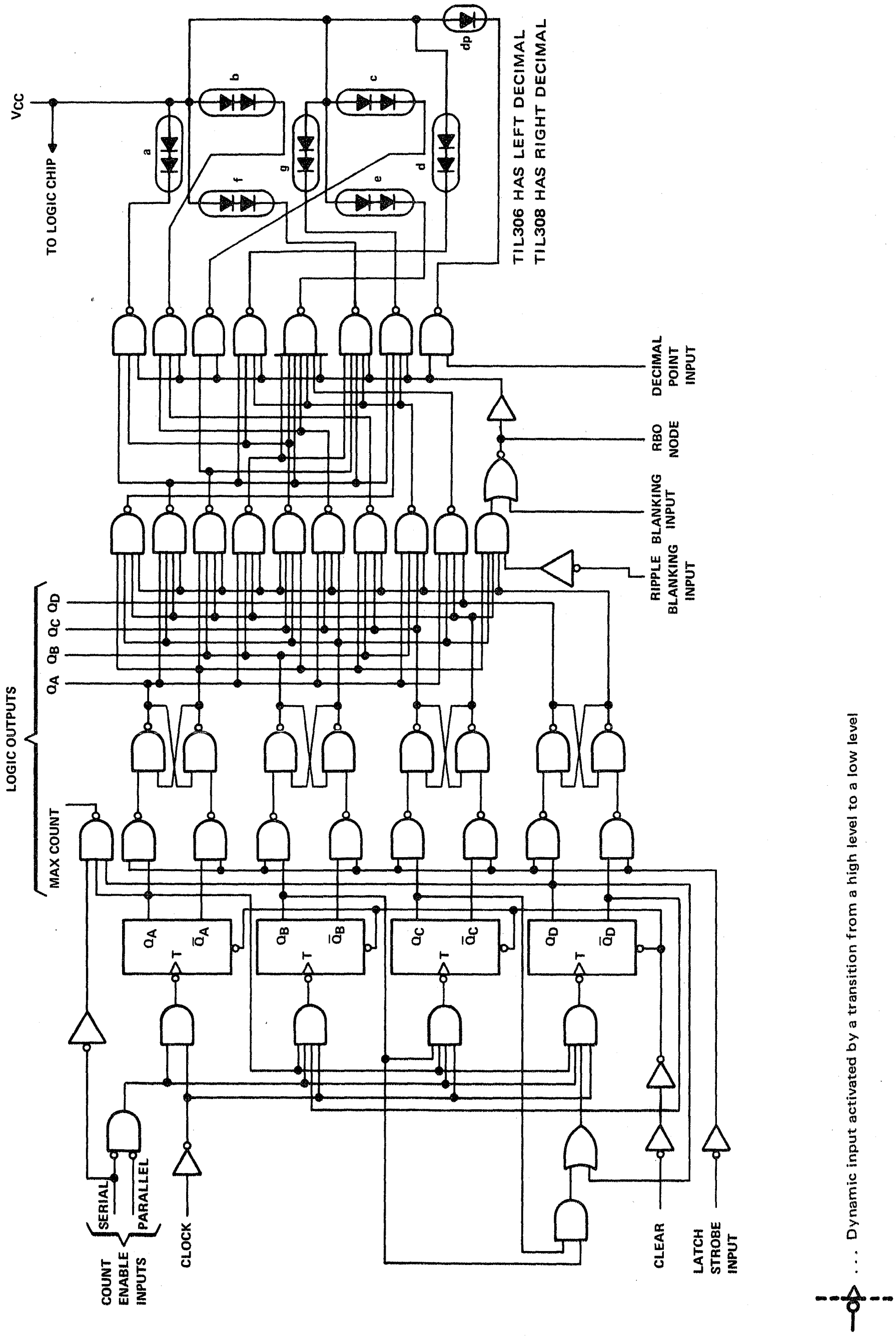
functional block diagram



SYNCHRONOUS BCD COUNTER, 4-BIT LATCH, DECODER/DRIVER, SEVEN-SEGMENT LED DISPLAY WITH DECIMAL POINT

8

1174

TEXAS INSTRUMENTS
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description

These internally-driven seven-segment light-emitting-diode (LED) displays contain a BCD counter, a four-bit latch, and a decoder/LED driver in a single 16-pin package. A description of the functions of the inputs and outputs of these devices follows:

FUNCTION	PIN NO.	DESCRIPTION
CLEAR INPUT	12	When low, resets and holds counter at 0. Must be high for normal counting.
CLOCK INPUT	15	Each positive-going transition will increment the counter provided that the circuit is in the normal counting mode (serial and parallel count enable inputs low, clear input high).
PARALLEL COUNT ENABLE INPUT (PCEI)	9	Must be low for normal counting mode. When high, counter will be inhibited. Logic level must not be changed when the clock is low.
SERIAL COUNT ENABLE INPUT (SCEI)	10	Must be low for normal counting mode, also must be low to enable maximum count output to go low. When high, counter will be inhibited and maximum count output will be driven high. Logic level must not be changed when the clock is low.
MAXIMUM COUNT OUTPUT	7	Will go low when the counter is at 9 and serial count enable input is low. Will return high when the counter changes to 0 and will remain high during counts 1 through 8. Will remain high (inhibited) as long as serial count enable input is high.
LATCH STROBE INPUT	5	When low, data in latches follow the data in the counter. When high, the data in the latches are held constant, and the counter may be operated independently.
LATCH OUTPUTS (Q_A, Q_B, Q_C, Q_D)	4, 1, 2, 3	The BCD data that drives the decoder can be stored in the 4-bit latch and is available at these outputs for driving other logic and/or processors. The binary weights of the outputs are: $Q_A = 1$, $Q_B = 2$, $Q_C = 4$, $Q_D = 8$.
DECIMAL POINT INPUT	13	Must be high to display decimal point. The decimal point is not displayed when this input is low or when the display is blanked.
BLANKING INPUT (BI)	14	When high, will blank (turn off) the entire display and force RBO low. Must be low for normal display. May be pulsed to implement intensity control of the display.
RIPPLE-BLANKING INPUT (RBI)	6	When the data in the latches is BCD 0, a low input will blank the entire display and force the RBO low. This input has no effect if the data in the latches is other than 0.
RIPPLE-BLANKING OUTPUT (RBO)	11	Supplies ripple-blanking information for the ripple-blanking input of the next decade. Provides a low if BI is high, or if RBI is low and the data in the latches is BCD 0; otherwise, this output is high. This pin has a resistive pull-up circuit suitable for performing a wire-AND function with any open-collector output. Whenever this pin is low the entire display will be blanked; therefore, this pin may be used as an active-low blanking input.

The TTL MSI circuits contain the equivalent of 86 gates on a single chip. Logic inputs and outputs are completely TTL/DTL compatible. The buffered inputs are implemented with relatively large resistors in series with the bases of the input transistors to lower drive-current requirements to one-half of that required for a standard Series 54/74 TTL input. The serial-carry input, actually two internal loads, is rated as one standard series 54/74 load.

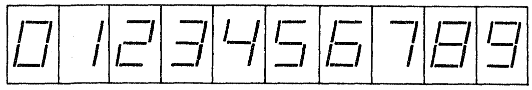
8

description (continued)

The logic outputs, except RBO, are active pull-up, and the latch outputs Q_A, Q_B, Q_C, and Q_D are each capable of driving three standard Series 54/74 loads at a low logic level or six loads at a high logic level while the maximum-count output is capable of driving five Series 54/74 loads at a low logic level or ten loads at a high logic level. The RBO node with passive pull-up serves as a ripple-blanking output with the capability to drive three Series 54/74 loads.

The LED driver outputs are designed specifically to maintain a relatively constant on-level current of approximately seven milliamperes through each LED segment and decimal point. All inputs are diode-clamped to minimize transmission-line effects, thereby simplifying system design. Maximum clock frequency is typically 18 megahertz and power dissipation is typically 600 milliwatts with all segments on.

The display format is as follows:



The displays may be interconnected to produce an n-digit display with the following features:

- Ripple-blanking input and output for blanking leading or trailing zeroes
- Floating-decimal-point logic capability
- Overriding blanking for suppressing entire display or pulse-modulation of LED brightness
- Dual count-enable inputs for parallel look-ahead and serial ripple logic to build high-speed fully synchronous, multidigit counter systems with no external logic, minimizing total propagation delay from the clock to the last latch output
- Provision for ripple-count cascading between packages
- Positive-edge-triggered synchronous BCD counter
- Parallel BCD data outputs available to drive logic processors or remote slaved displays simultaneously with data being displayed
- Latch strobe input allows counter to operate while a previous data point is displayed
- Reset-to-zero capability with clear input.

absolute maximum ratings over operating case temperature range (unless otherwise noted)

Supply Voltage, V_{CC} (See Note 1): Continuous . . . . 5.5 V
Nonrepetitive Peak, $t_w \leq 100$ ms . . . . 7 V
Input Voltage (See Note 1) . . . . 5.5 V
Operating Case Temperature Range (See Note 2) . . . . 0°C to 85°C
Storage Temperature Range . . . . −25°C to 85°C

NOTES: 1. Voltage values are with respect to network ground terminal.
2. Case temperature is the surface temperature of the plastic encapsulant measured directly over the integrated circuit. Forced-air cooling may be required to maintain this temperature.

recommended operating conditions

			MIN	NOM	MAX	UNIT
Supply Voltage, V_{CC}			4.75	5	5.25	V
Normalized Fan-Out from Each Output, N (to Series 54/74 Integrated Circuits)	Low Logic Level	Q_A, Q_B, Q_C, Q_D, RBO			3	
		Maximum Count			5	
	High Logic Level	RBO			3	
		Q_A, Q_B, Q_C, Q_D			6	
		Maximum Count			10	
Clock Pulse Width, $t_{w(clock)}$		High Logic Level	25			ns
		Low Logic Level	55			
Clear Pulse Width, $t_{w(clear)}$			25			ns
Latch Strobe Pulse Width, $t_{w(latch\ strobe)}$			45			ns
Setup Time, t_{setup} (See Note 3)		Serial Carry and Parallel Carry	30			ns
		Clear Inactive State	60			

NOTE 3: Minimum setup time is the interval immediately preceding the positive-going edge of the clock pulse during which interval the data to be recognized must be maintained at the input to ensure its recognition.

operating characteristics at 25°C case temperature

PARAMETER			TEST CONDITIONS	MIN	TYP‡	MAX	UNIT
I_v	Luminous Intensity (See Note 4)	Figure 8	$V_{CC} = 5$ V	700	1200		μcd
		Decimal Point		40	70		μcd
λ_p	Wavelength at Peak Emission		$V_{CC} = 5$ V, See Note 5	640	660	680	nm
$\Delta\lambda$	Spectral Bandwidth		$V_{CC} = 5$ V, See Note 5		20		nm
V_{IH}	High-Level Input Voltage			2			V
V_{IL}	Low-Level Input Voltage					0.8	V
V_{IK}	Input Clamp Voltage		$V_{CC} = 4.75$ V, $I_I = -12$ mA			−1.5	V
V_{OH}	High-Level Output Voltage	RBO	$V_{CC} = 4.75$ V, $I_{OH} = -120$ μA	2.4			V
		Q_A, Q_B, Q_C, Q_D	$V_{CC} = 4.75$ V, $I_{OH} = -240$ μA				
		Maximum Count	$V_{CC} = 4.75$ V, $I_{OH} = -400$ μA				
V_{OL}	Low-Level Output Voltage (See Note 6)	Q_A, Q_B, Q_C, Q_D, RBO	$V_{CC} = 4.75$ V, $I_{OL} = 4.8$ mA			0.4	V
		Maximum Count	$V_{CC} = 4.75$ V, $I_{OL} = 8$ mA				
I_I	Input Current at Maximum Input Voltage		$V_{CC} = 5.25$ V, $V_I = 5.5$ V			1	mA
I_{IH}	High-Level Input Current	Serial Carry	$V_{CC} = 5.25$ V, $V_I = 2.4$ V			40	μA
		RBO Node		−0.12	−0.5		mA
		Other Inputs				20	μA
I_{IL}	Low-Level Input Current	Serial Carry	$V_{CC} = 5.25$ V, $V_I = 0.4$ V			−1.6	mA
		RBO Node			−1.5	−2.4	
		Other Inputs				−0.8	
I_{OS}	Short-Circuit Output Current	Q_A, Q_B, Q_C, Q_D	$V_{CC} = 5.25$ V	−9		−27.5	mA
		Maximum Count		−15		−55	
I_{CC}	Supply Current		$V_{CC} = 5.25$ V, See Note 5		120	200	mA

‡All typical values are at $V_{CC} = 5$ V.

NOTES: 4. Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

5. These parameters are measured with all LED segments and the decimal point on.

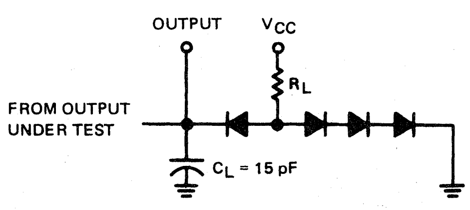
6. This parameter is measured with the display blanked.

8

switching characteristics, $V_{CC} = 5$ V, $T_C = 25$°C

PARAMETER§	FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	MIN	TYP	MAX	UNIT
f_{max}				12	18		MHz
t_{PLH}	Serial Look-Ahead	Maximum Count	$C_L = 15$ pF, $R_L = 560\ \Omega$, See Figure 1		12		ns
t_{PHL}					23		
t_{PLH}	Clock	Maximum Count			26		ns
t_{PHL}					29		
t_{PLH}	Clock	Q_A, Q_B, Q_C, Q_D	$C_L = 15$ pF, $R_L = 1.2$ kΩ, See Figure 1		28		ns
t_{PHL}					38		
t_{PHL}	Clear	Q_A, Q_B, Q_C, Q_D			57		ns

§f_{max} ≡ Maximum clock frequency
t_{PLH} ≡ Propagation delay time, low-to-high-level output
t_{PHL} ≡ Propagation delay time, high-to-low-level output



NOTES: A. C_L includes probe and jig capacitance.
B. All diodes are 1N3064.

LOAD CIRCUIT—FIGURE 1

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

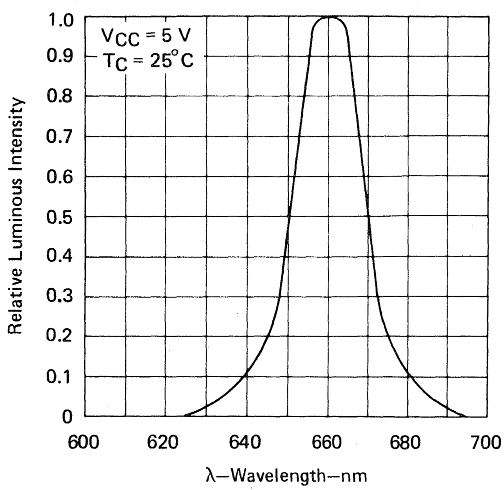


FIGURE 2

RELATIVE LUMINOUS INTENSITY vs CASE TEMPERATURE

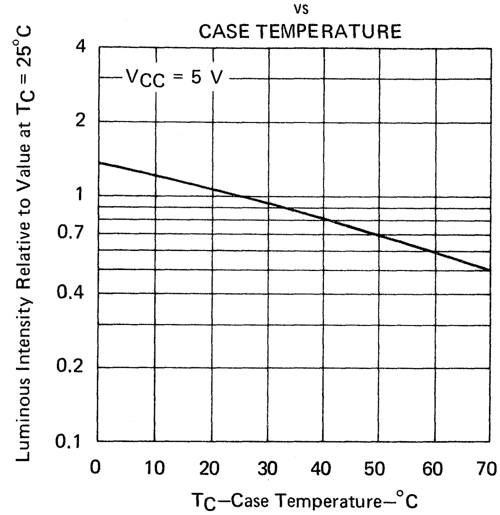


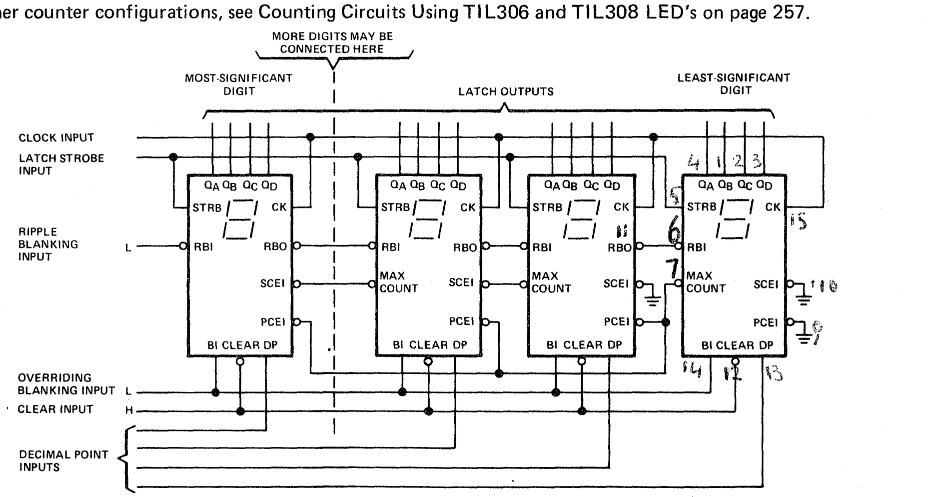
FIGURE 3

TYPICAL APPLICATION DATA

This application demonstrates how the displays may be cascaded for N-bit display applications. It features:

- Synchronous, look-ahead counting
- Ripple blanking for leading zeros
- Overriding blanking for total suppression or intensity modulation of display
- Direct parallel clear
- Latch strobe permits counter to acquire data for the next display while viewing current display.

For other counter configurations, see Counting Circuits Using TIL306 and TIL308 LED's on page 257.



†The serial carry input of the least-significant digit is normally grounded; however, it may be used as a count-enable control for the entire counter (high to disable, low to count) provided the logic level on this pin is not changed while the clock line is low or false counting may result.

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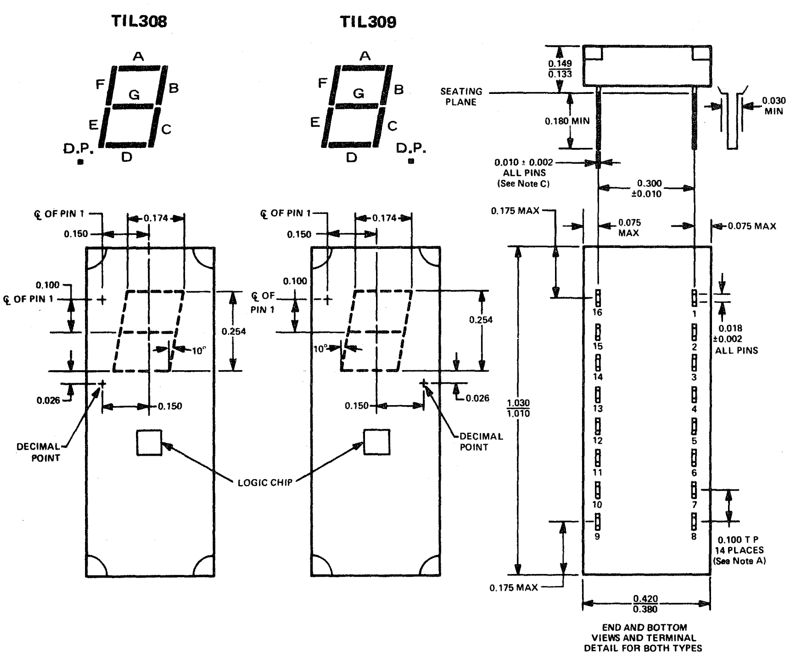
BULLETIN NO. DL-S 7611550, MARCH 1972—REVISED MARCH 1976

SOLID-STATE VISIBLE DISPLAYS WITH INTEGRAL TTL MSI CIRCUIT CHIP FOR USE IN ALL SYSTEMS REQUIRING A DISPLAY OF BCD DATA

- 0.270-Inch-High Character
- High Luminous Intensity
- TIL308 Has Left Decimal
- TIL309 Has Right Decimal
- Easy System Interface
- Wide Viewing Angle
- Internal TTL MSI Chip with Latch, Decoder, and Driver
- Constant-Current Drive for Light-Emitting Diodes

mechanical data

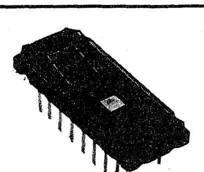
The display chips and TTL MSI chip are mounted on a header and this assembly is then cast within a red, electrically nonconductive, transparent plastic compound. Multiple displays may be mounted on 0.450-inch centers.



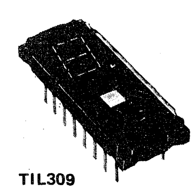
PIN ASSIGNMENTS FOR BOTH TYPES

PIN 1	LATCH OUTPUT Q_B (BINARY WEIGHT 2)
PIN 2	LATCH OUTPUT Q_C (BINARY WEIGHT 4)
PIN 3	LATCH OUTPUT Q_D (BINARY WEIGHT 8)
PIN 4	LATCH OUTPUT Q_A (BINARY WEIGHT 1)
PIN 5	LATCH STROBE INPUT
PIN 6	LATCH DATA INPUT C (BINARY WEIGHT 4)
PIN 7	LATCH DATA INPUT D (BINARY WEIGHT 8)
PIN 8	GROUND
PIN 9	NO INTERNAL CONNECTION
PIN 10	LATCH DATA INPUT B (BINARY WEIGHT 2)
PIN 11	BLANKING INPUT
PIN 12	LATCH DATA INPUT DP
PIN 13	LED TEST
PIN 14	LATCH OUTPUT DP
PIN 15	LATCH DATA INPUT A (BINARY WEIGHT 1)
PIN 16	SUPPLY VOLTAGE, V_{CC}

NOTES: A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within 0.010 of its true longitudinal poistion relative to pins 1 and 16.
B. Centerlines of character segments and decimal points are shown as dashed lines. Associated dimensions are nominal.
C. Lead dimensions are not controlled above the seating plane.
D. All dimensions are in inches unless otherwise specified.



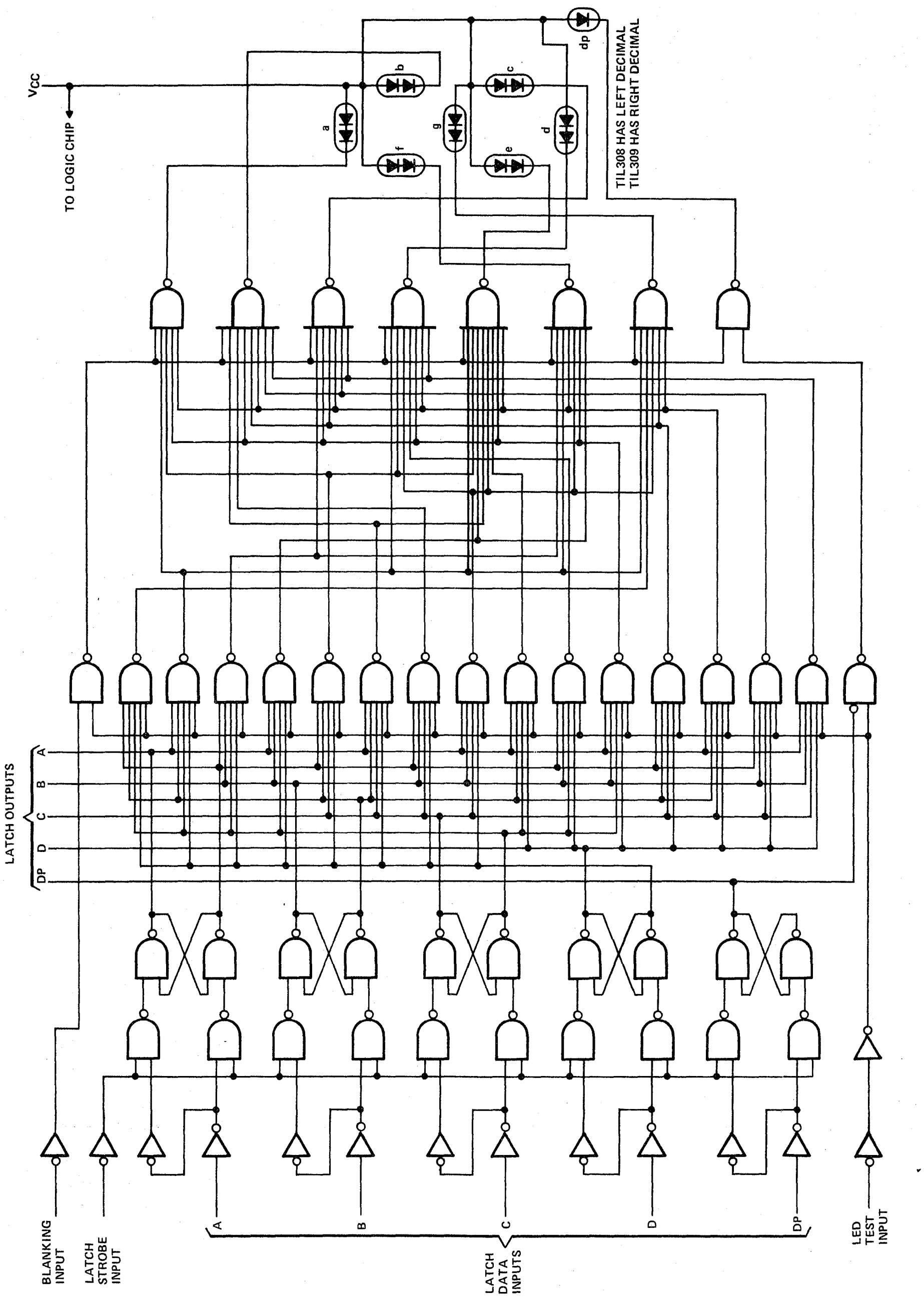
TIL308



TIL309

8

functional block diagram



8

description

These internally-driven seven-segment light-emitting-diode (LED) displays contain a five-bit latch and a decoder/LED driver in a single 16-pin package. A description of the functions of the inputs and outputs of these devices follows:

FUNCTION	PIN NO.	DESCRIPTION
LATCH STROBE INPUT	5	When low, the data in the latches follow the data on the latch inputs. When high, the data in the latches are held constant and are unaffected by new data on the latch inputs.
LATCH DATA INPUTS A, B, C, D, DP	15, 10, 6, 7, 12	Data on these inputs are entered into the latches under the control of the latch strobe input. The binary weights of the inputs are: A = 1, B = 2, C = 4, D = 8. DP is decimal point latch data input.
LATCH OUTPUTS Q_A, Q_B, Q_C, Q_D, Q_{DP}	4, 1, 2, 3, 14	The BCD data that drives the decoder is stored in the five latches and is available at these outputs. The binary weights of the outputs are: $Q_A = 1$, $Q_B = 2$, $Q_C = 4$, $Q_D = 8$. Q_{DP} is decimal point latch output.
BLANKING INPUT	11	When low, will blank (turn off) the entire display. Must be high for normal operation of the display.
LED TEST INPUT	13	When low, will turn on the entire display, overriding the data in the latches and the blanking input. Must be high for normal operation of the display.

FUNCTION TABLE

FUNCTION	LATCH INPUTS						BLANKING	LED	LATCH OUTPUTS					DISPLAY	
	D	C	B	A	DP	STROBE	INPUT	TEST	Q_D	Q_C	Q_B	Q_A	Q_{DP}	TIL308	TIL309
0	L	L	L	L	L	L	H	H	L	L	L	L	L	0	0
1	L	L	L	H	H	L	H	H	L	L	L	H	H	.1	1.
2	L	L	H	L	L	L	H	H	L	L	H	L	L	2	2
3	L	L	H	H	H	L	H	H	L	L	H	H	H	.3	3.
4	L	H	L	L	L	L	H	H	L	H	L	L	L	4	4
5	L	H	L	H	H	L	H	H	L	H	L	H	H	.5	5.
6	L	H	H	L	L	L	H	H	L	H	H	L	L	6	6
7	L	H	H	H	H	L	H	H	L	H	H	H	H	.7	7.
8	H	L	L	L	L	L	H	H	H	L	L	L	L	8	8
9	H	L	L	H	H	L	H	H	H	L	L	H	H	.9	9.
A	H	L	H	L	L	L	H	H	H	L	H	L	L	A	A
MINUS SIGN	H	L	H	H	H	L	H	H	H	L	H	H	H	.-	-.
C	H	H	L	L	L	L	H	H	H	H	L	L	L	C	C
BLANK	H	H	L	H	H	L	H	H	H	H	L	H	H	.	.
E	H	H	H	L	L	L	H	H	H	H	H	L	L	E	E
F	H	H	H	H	H	L	H	H	H	H	H	H	H	.F	F.
BLANK	X	X	X	X	X	X	L	H	X	X	X	X	X		
LED TEST	X	X	X	X	X	X	X	L	X	X	X	X	X	.8	8.

H = high level, L = low level, X = irrelevant.
DP input has arbitrarily been shown activated (high) on every other line of the table.

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description (continued)

The TTL MSI circuits contain the equivalent of 78 gates on a single chip. Logic inputs and outputs are completely TTL/DTL compatible. The buffered inputs are implemented with relatively large resistors in series with the bases of the input transistors to lower drive-current requirements to one-half of that required for a standard Series 54/74 TTL input.

Some of the additional features of these displays are as follows:

- Latched BCD and decimal point logic outputs provided to drive logic processors simultaneously with the displayed data
- Minimum number of inputs required . . . 4-line BCD plus decimal point
- Overriding blanking for suppressing entire display or for pulse-modulation of LED brightness
- LED test input to simultaneously turn on all display segments and decimal point
- Can be operated in a real-time mode or latched-update-only mode by use of the latch strobe input
- Displays numbers 0 thru 9 as well as A, C, E, F, or minus sign
- Can be blanked by entry of BCD 13 or by use of the blanking input
- Decimal point controlled independently with decimal-point latch
- Constant-current-source TTL-LED interface for optimum performance.

The latch outputs except Q_{DP} are active pull-up, and each one, except Q_{DP}, is capable of driving three standard Series 54/74 loads. The LED driver outputs are designed specifically to maintain a relatively constant on-level current of approximately seven milliamperes through each LED segment and decimal point. All inputs are diode-clamped to minimize transmission-line effects, thereby simplifying system design. Power dissipation is typically 575 milliwatts with all segments on.

absolute maximum ratings over operating case temperature range (unless otherwise noted)

Supply Voltage, V_{CC} (See Note 1): Continuous	5.5 V
Nonrepetitive Peak, $t_w \leq 100$ ms	7 V
Input Voltage (See Note 1)	5.5 V
Operating Case Temperature Range (See Note 2)	0°C to 85°C
Storage Temperature Range	–25°C to 85°C

NOTES: 1. Voltage values are with respect to network ground terminal.
2. Case temperature is the surface temperature of the plastic encapsulant measured directly over the integrated circuit. Forced-air cooling may be required to maintain this temperature.

recommended operating conditions

			MIN	NOM	MAX	UNIT
Supply Voltage, V_{CC}			4.75	5	5.25	V
Normalized Fan-out from each output, N (to Series 54/74 Integrated Circuits)	Low Logic Level	Q_{DP}			1	
		Q_A, Q_B, Q_C, Q_D			3	
	High Logic Level	Q_{DP}			3	
		Q_A, Q_B, Q_C, Q_D			6	
Latch Strobe Pulse Width, t_w			45			ns
Setup Time, t_{setup} (See Note 3)			60			ns
Hold Time, t_{hold} (See Note 4)			0			ns

NOTES: 3. Minimum setup time is the interval immediately preceeding the positive-going transition of the latch strobe during which interval the data to be latched must be maintained at the latch inputs to ensure its recognition.
4. Minimum hold time is the interval immediately following the positive-going transition of the latch strobe during which interval the data to be latched must be maintained at the latch inputs to ensure its continued recognition.

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TEXAS INSTRUMENTS
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operating characteristics at 25°C case temperature

PARAMETER			TEST CONDITIONS	MIN	TYP†	MAX	UNIT
I_V	Luminous Intensity (See Note 5)	Figure 8	V_{CC} = 5 V	700	1200		μcd
		Decimal Point		40	70		
λp	Wavelength at Peak Emission		V_{CC} = 5 V, See Note 6	640	660	680	nm
Δλ	Spectral Bandwidth		V_{CC} = 5 V, See Note 6		20		nm
V_{IH}	High-Level Input Voltage			2			V
V_{IL}	Low-Level Input Voltage					0.8	V
V_{IK}	Input Clamp Voltage		V_{CC} = 4.75 V, I_I = −12 mA			−1.5	V
V_{OH}	High-Level Output Voltage	Q_{DP}	V_{CC} = 4.75 V, I_{OH} = −120 μA	2.4			V
		Q_A, Q_B, Q_C, Q_D	V_{CC} = 4.75 V, I_{OH} = −240 μA				
V_{OL}	Low-Level Output Voltage (See Note 7)	Q_{DP}	V_{CC} = 4.75 V, I_{OL} = 1.6 mA			0.4	V
		Q_A, Q_B, Q_C, Q_D	V_{CC} = 4.75 V, I_{OL} = 4.8 mA				
I_I	Input Current at Maximum Input Voltage		V_{CC} = 5.25 V, V_I = 5.5 V			1	mA
I_{IH}	High-Level Input Current		V_{CC} = 5.25 V, V_I = 2.4 V			20	μA
I_{IL}	Low-Level Input Current		V_{CC} = 5.25 V, V_I = 0.4 V			−0.8	mA
I_{OS}	Short-Circuit Output Current	Q_A, Q_B, Q_C, Q_D	V_{CC} = 5.25 V	−9		−27.5	mA
		Q_{DP}		−1		−3.2	
I_{CC}	Supply Current		V_{CC} = 5.25 V, All Inputs at 0 V		115	180	mA

†All typical values are at V_{CC} = 5 V.

NOTES: 5. Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

6. These parameters are measured with all LED segments and the decimal point on.

7. This parameter is measured with the display blanked.

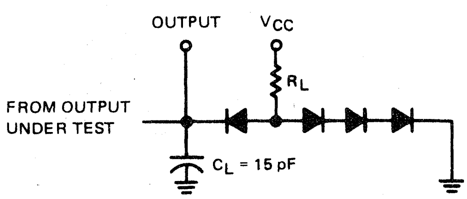
switching characteristics, V_{CC} = 5 V, T_C = 25°C

PARAMETER	FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PLH}	A, B, C, D, DP	Q_A, Q_B, Q_C, Q_D, Q_{DP}	C_L = 15 pF, R_L = 1.2 kΩ, See Figure 1		35		ns
t_{PHL}					40		ns

t_{PLH} ≡ Propagation delay time, low-to-high-level output
t_{PHL} ≡ Propagation delay time, high-to-low-level output

8

PARAMETER MEASUREMENT INFORMATION



NOTES: A. C_L includes probe and jig capacitance.

B. All diodes are 1N3064.

C. Measurements made with latch strobe input grounded.

LOAD CIRCUIT—FIGURE 1

TYPICAL CHARACTERISTICS

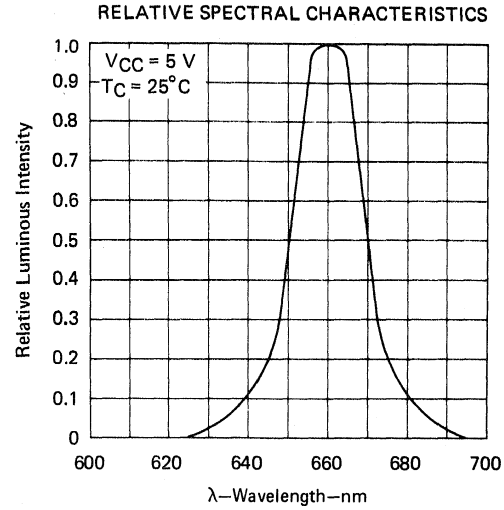


FIGURE 2

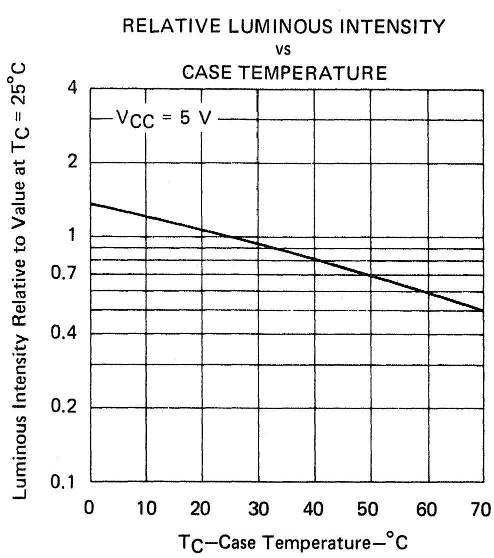


FIGURE 3

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

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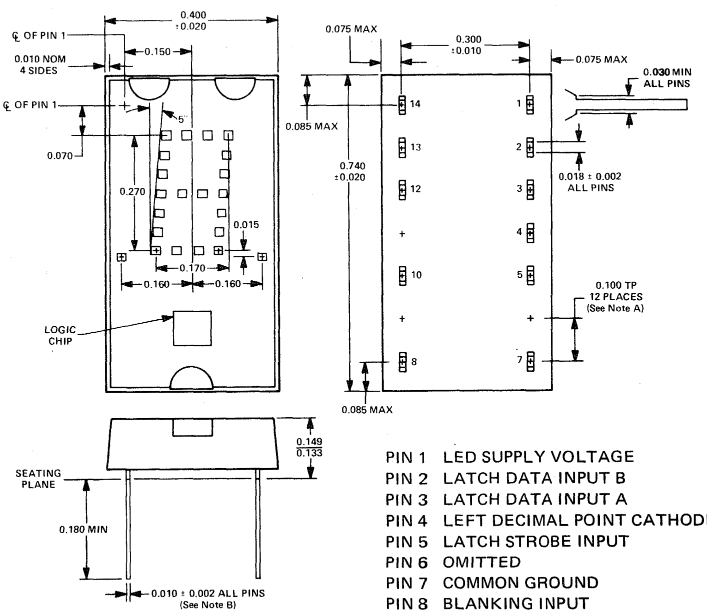
BULLETIN NO. DL-S 7611653, MARCH 1972–REVISED MARCH 1976

SOLID-STATE VISIBLE HEXADECIMAL DISPLAY WITH INTEGRAL TTL CIRCUIT TO ACCEPT, STORE, AND DISPLAY 4-BIT BINARY DATA

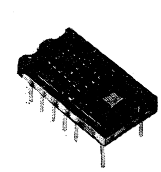
- 0.300-Inch-High Character
- High Brightness
- Left-and-Right-Hand Decimals
- Separate LED and Logic Power Supplies May Be Used
- Easy System Interface
- Wide Viewing Angle
- Internal TTL MSI Chip with Latch, Decoder, and Driver
- Operates from 5-Volt Supply
- Constant-Current Drive for Hexadecimal Characters

mechanical data

The display chips and TTL MSI chip are mounted on a header and this assembly is then cast within a red, electrically nonconductive, transparent plastic compound. Multiple displays may be mounted on 0.450-inch centers.



PIN 1 LED SUPPLY VOLTAGE
PIN 2 LATCH DATA INPUT B
PIN 3 LATCH DATA INPUT A
PIN 4 LEFT DECIMAL POINT CATHODE
PIN 5 LATCH STROBE INPUT
PIN 6 OMITTED
PIN 7 COMMON GROUND
PIN 8 BLANKING INPUT
PIN 9 OMITTED
PIN 10 RIGHT DECIMAL POINT CATHODE
PIN 11 OMITTED
PIN 12 LATCH DATA INPUT D
PIN 13 LATCH DATA INPUT C
PIN 14 LOGIC SUPPLY VOLTAGE, V_{CC}



NOTES: A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within ±0.010 of its true longitudinal position relative to pins 1 and 14.
B. Lead dimensions are not controlled above the seating plane.
C. Dimensions associated with position of LED's are between centerlines and are nominal.
D. All dimensions are in inches unless otherwise specified.

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TEXAS INSTRUMENTS
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description

This hexadecimal display contains a four-bit latch, decoder, driver, and 4 X 7 light-emitting-diode (LED) character with two externally-driven decimal points in a 14-pin package. A description of the functions of the inputs of this device follows.

FUNCTION	PIN NO.	DESCRIPTION
LATCH STROBE INPUT	5	When low, the data in the latches follow the data on the latch data inputs. When high, the data in the latches will not change. If the display is blanked and then restored while the enable input is high, the previous character will again be displayed.
BLANKING INPUT	8	When high, the display is blanked regardless of the levels of the other inputs. When low, a character is displayed as determined by the data in the latches. The blanking input may be pulsed for intensity modulation.
LATCH DATA INPUTS (A, B, C, D)	3, 2, 13, 12	Data on these inputs are entered into the latches when the enable input is low. The binary weights of these inputs are A = 1, B = 2, C = 4, D = 8.
DECIMAL POINT CATHODES	4, 10	These LEDs are not connected to the logic chip. If a decimal point is used, an external resistor or other current-limiting mechanism must be connected in series with it.
LED SUPPLY	1	This connection permits the user to save on regulated V_{CC} current by using a separate LED supply, or it may be externally connected to the logic supply (V_{CC}).
LOGIC SUPPLY (V_{CC})	14	Separate V_{CC} connection for the logic chip.
COMMON GROUND	7	This is the negative terminal for all logic and LED currents except for the decimal points.

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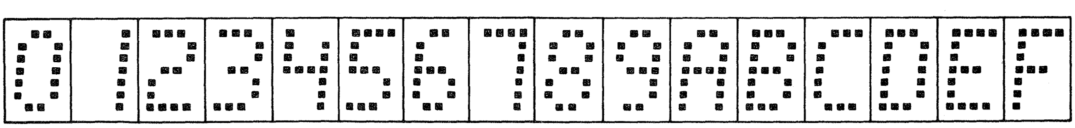
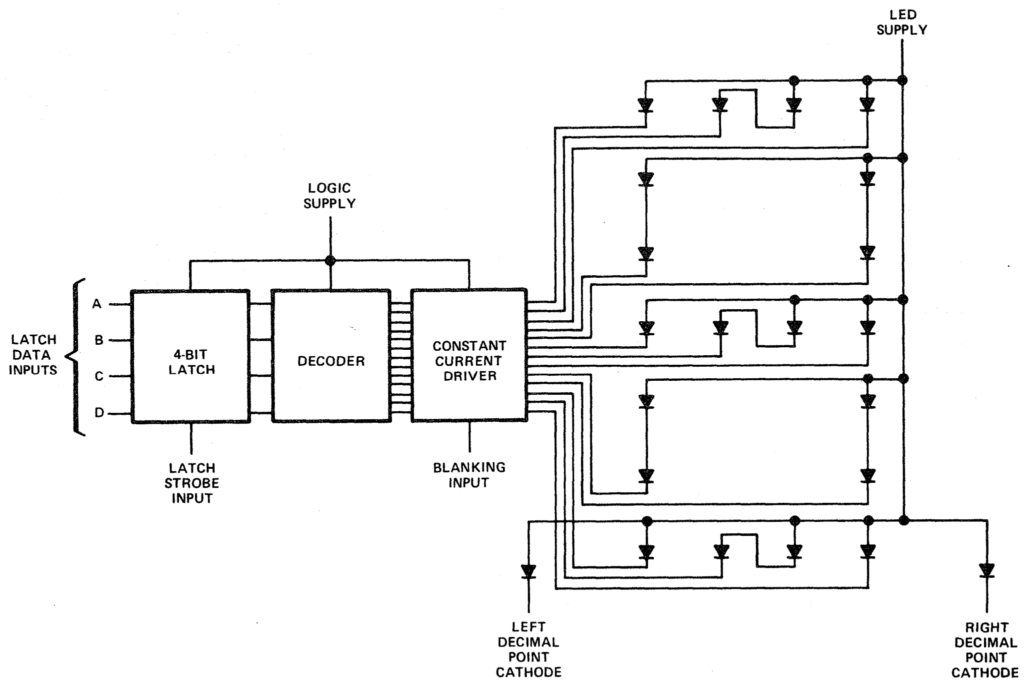
The LED driver outputs are designed to maintain a relatively constant on-level current of approximately five milliamperes through each of the LED's forming the hexadecimal character. This current is virtually independent of the LED supply voltage within the recommended operating conditions. Drive current varies slightly with changes in logic supply voltage resulting in a change in luminous intensity as shown in Figure 2. This change will not be noticeable to the eye. The decimal point anodes are connected to the LED supply; the cathodes are connected to external pins. Since there is no current limiting built into the decimal point circuits, this must be provided externally if the decimal points are used.

The resultant displays for the values of the binary data in the latches are as shown below.



0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

functional block diagram



8

absolute maximum ratings over operating case temperature range (unless otherwise noted)

Logic Supply Voltage, V_{CC} (See Note 1)	7 V
LED Supply Voltage (See Note 1)	7 V
Input Voltage (Pins 2, 3, 5, 8, 12, 13; See Note 1)	5.5 V
Decimal Point Current	20 mA
Operating Case Temperature Range (See Note 2)	0°C to 85°C
Storage Temperature Range	–25°C to 85°C

NOTES: 1. Voltage values are with respect to common ground terminal.
2. Case temperature is the surface temperature of the plastic encapsulant measured directly over the integrated circuit. Forced-air cooling may be required to maintain this temperature.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Logic Supply Voltage, V_{CC}	4.5	5	5.5	V
LED Supply Voltage, V_{LED}	4	5	5.5	V
Decimal Point Current, $I_{F(DP)}$		5		mA
Latch Strobe Pulse Width, t_w	40			ns
Setup Time, t_{setup} (See Note 3)	50			ns
Hold Time, t_{hold} (See Note 4)	40			ns

NOTES: 3. Minimum setup time is the interval immediately preceding the positive-going transition of the latch strobe input during which interval the data to be displayed must be maintained at the latch data inputs to ensure its recognition.
4. Minimum hold time is the interval immediately following the positive-going transition of the latch strobe input during which interval the data to be displayed must be maintained at the latch data inputs to ensure its continued recognition.

TEXAS INSTRUMENTS
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POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

operating characteristics at 25°C case temperature

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V	Luminous Intensity (See Note 4)	Average Per Character LED	V_{CC} = 5 V, V_{LED} = 5 V, See Note 5	35	100		μcd
		Each decimal	$I_{F(DP)}$ = 5 mA	35	100		μcd
λ_p	Wavelength at Peak Emission		V_{CC} = 5 V, V_{LED} = 5 V,	640	660	680	nm
$\Delta\lambda$	Spectral Bandwidth		$I_{F(DP)}$ = 5 mA, See Note 6		20		nm
V_{IH}	High-Level Input Voltage			2			V
V_{IL}	Low-Level Input Voltage					0.8	V
V_{IK}	Input Clamp Voltage		V_{CC} = 4.75 V, I_I = −12 mA			−1.5	V
I_I	Input Current at Maximum Input Voltage		V_{CC} = 5.5 V, V_I = 5.5 V			1	mA
I_{IH}	High-Level Input Current		V_{CC} = 5.5 V, V_I = 2.4 V			40	μA
I_{IL}	Low-Level Input Current		V_{CC} = 5.5 V, V_I = 0.4 V			−1.6	mA
I_{CC}	Logic Supply Current		V_{CC} = 5.5 V, V_{LED} = 5.5 V		60	90	mA
I_{LED}	LED Supply Current		$I_{F(DP)}$ = 5 mA, All inputs at 0 V		45	90	mA

NOTES: 4. Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.
5. This parameter is measured with A displayed, then again with E displayed.
6. These parameters are measured with .B. displayed.

TYPICAL CHARACTERISTICS

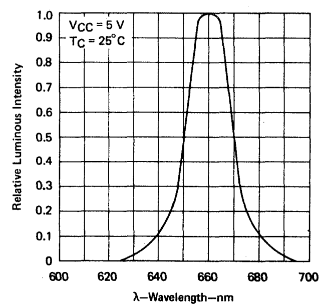

FIGURE 1

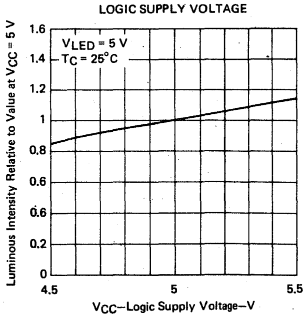

FIGURE 2

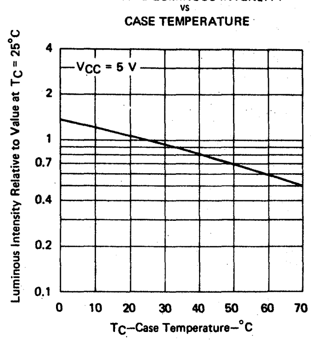

FIGURE 3

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TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

BULLETIN NO. DL-S 7612129, NOVEMBER 1974—REVISED MARCH 1976

SOLID-STATE VISIBLE DISPLAYS WITH RED, GREEN, OR AMBER CHARACTERS

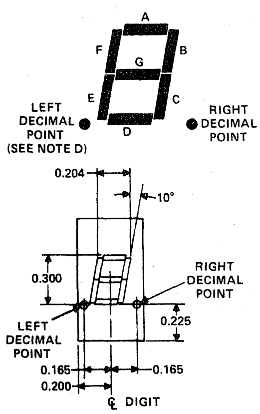
- 0.300-Inch-High Characters
- Continuous Uniform Segments
- Wide Viewing Angle
- High Contrast
- Categorized for Uniformity of Luminous Intensity among Units within Each Category

	SEVEN SEGMENTS WITH RIGHT AND LEFT DECIMALS, COMMON ANODE	SEVEN SEGMENTS WITH RIGHT DECIMAL, COMMON CATHODE	PLUS/MINUS ONE WITH LEFT DECIMAL
RED	TIL312	TIL313	TIL327
GREEN	TIL314	TIL315	TIL328
AMBER	TIL316	TIL317	TIL329

mechanical data

The display chips are mounted on a header and this assembly is then molded within an electrically nonconductive plastic case. To optimize device performance, materials are used that are limited to certain solvents for cleaning operations. It is recommended that only freon TF, isopropanol, or water be used.

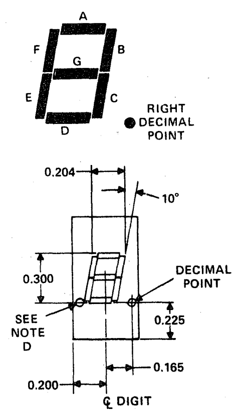
TIL312
TIL314
TIL316



PIN 1–CATHODE A
PIN 2–CATHODE F
PIN 3–ANODE: DIGIT & DECIMAL
PIN 4–OMITTED
PIN 5–OMITTED
PIN 6–CATHODE LEFT DECIMAL
PIN 7–CATHODE E
PIN 8–CATHODE D
PIN 9–CATHODE RIGHT DECIMAL
PIN 10–CATHODE C
PIN 11–CATHODE G
PIN 12–OMITTED
PIN 13–CATHODE B
PIN 14–ANODE: DIGIT & DECIMAL

PIN 3 IS INTERNALLY CONNECTED TO PIN 14

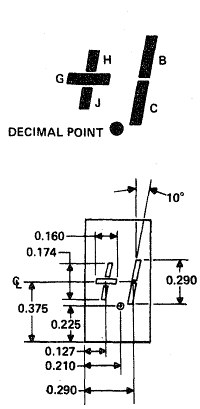
TIL313
TIL315
TIL317



PIN 1–OMITTED
PIN 2–CATHODE: DIGIT & DECIMAL
PIN 3–ANODE F
PIN 4–ANODE G
PIN 5–ANODE E
PIN 6–ANODE D
PIN 7–OMITTED
PIN 8–OMITTED
PIN 9–CATHODE: DIGIT & DECIMAL
PIN 10–ANODE DECIMAL
PIN 11–ANODE C
PIN 12–ANODE B
PIN 13–ANODE A
PIN 14–OMITTED

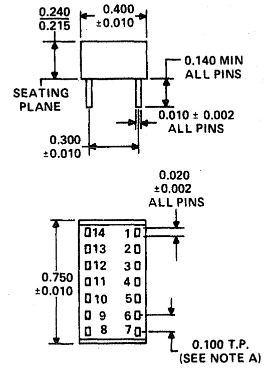
PIN 2 IS INTERNALLY CONNECTED TO PIN 9

TIL327
TIL328
TIL329



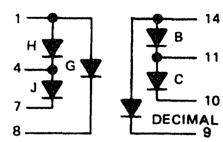
PIN 1–ANODE H, ANODE G
PIN 2–OMITTED
PIN 3–OMITTED
PIN 4–CATHODE H, ANODE J
PIN 5–OMITTED
PIN 6–OMITTED
PIN 7–CATHODE J
PIN 8–CATHODE G
PIN 9–CATHODE DECIMAL
PIN 10–CATHODE C
PIN 11–CATHODE B, ANODE C
PIN 12–OMITTED
PIN 13–OMITTED
PIN 14–ANODE B, ANODE DECIMAL

SEE SCHEMATIC DIAGRAM AT RIGHT



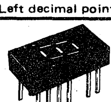
END AND BOTTOM VIEWS AND TERMINAL DETAIL FOR ALL NINE TYPES

SCHEMATIC FOR TIL327, TIL328, AND TIL329

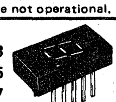


NOTES: A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within 0.010 of its true longitudinal position relative to pins 4 and 11.
B. All dimensions associated with segment and decimal point locations are nominal.
C. All dimensions are in inches unless otherwise specified.
D. Left decimal points of TIL313, TIL315, and TIL317 are not operational.

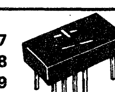
TIL312
TIL314
TIL316



TIL313
TIL315
TIL317



TIL327
TIL328
TIL329



8

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature, Each Segment or Decimal Point . . . . 3 V
Peak Forward Current at (or below) 25°C Free-Air Temperature,
Each Segment or Decimal Point . . . . 150 mA
Average Forward Current at (or below) 25°C Free-Air Temperature (See Notes 1 and 2),
Each Segment or Decimal Point . . . . 25 mA
Operating Free-Air Temperature Range . . . . −25°C to 85°C
Storage Temperature Range . . . . −25°C to 85°C
Lead Temperature 1/16 Inch Below Seating Plane for 5 Seconds . . . . 230°C

NOTES: 1. This average value applies for any 10-ms period.
2. Derate linearly to 10 mA at 85°C free-air temperature at the rate of 0.25 mA/°C.

operating characteristics of each segment or decimal point at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	TIL312, TIL313, TIL327			TIL314, TIL315, TIL328			TIL316, TIL317, TIL329			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
I_V	Luminous Intensity (See Note 3)	Average per Segment	I_F = 20 mA per segment or decimal point	250	500		150	320		150	340		µcd
		Decimal Point		100	200		60	130		60	135		
	Segment-to-Segment Luminous Intensity Ratio				1.5:1			1.5:1			1.5:1		
λ_p	Wavelength at Peak Emission			640	655	680		565			590		nm
$\Delta\lambda$	Spectral Bandwidth				20			40			40		nm
V_F	Static Forward Voltage			1.5	1.7	2		2.5	3.5		2.5	3.5	V
I_R	Static Reverse Current		V_R = 3 V		10			10			10		µA

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NOTE 3: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve. Segments H and J are totaled and considered as one segment for this parameter.

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES TIL321 THRU TIL326, TIL330 THRU TIL332
NUMERIC DISPLAYS

BULLETIN NO. DL-S 7612382, MARCH 1976

SOLID-STATE VISIBLE DISPLAYS WITH RED, GREEN, OR AMBER TRANSPARENT PLASTIC ENCAPSULATION

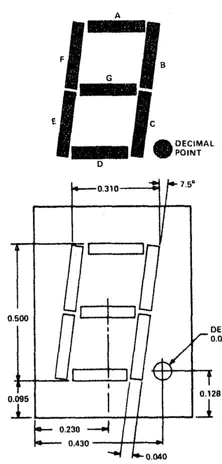
- 0.500-Inch-High Characters
- Continuous Uniform Segments
- Wide Viewing Angle
- High Contrast
- Categorized for Uniformity of Luminous Intensity among Units within Each Category
- Low Power Requirements

	SEVEN SEGMENTS WITH RIGHT DECIMAL, COMMON ANODE	SEVEN SEGMENTS WITH RIGHT DECIMAL, COMMON CATHODE	PLUS/MINUS ONE WITH RIGHT DECIMAL
RED	TIL321	TIL322	TIL330
GREEN	TIL323	TIL324	TIL331
AMBER	TIL325	TIL326	TIL332

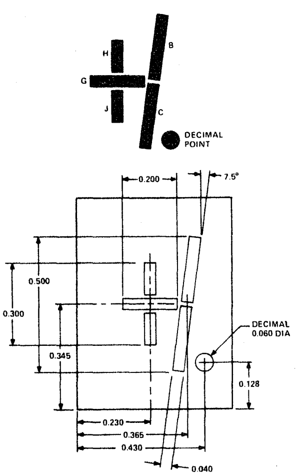
mechanical data

The light-emitting diode chips are mounted on a printed-circuit board, which, together with a one-piece reflector assembly, is encased within a transparent plastic case and sealed with epoxy. To optimize device performance, materials are used that are limited to certain solvents for cleaning operations. It is recommended that only freon TF, isopropanol, or water be used.

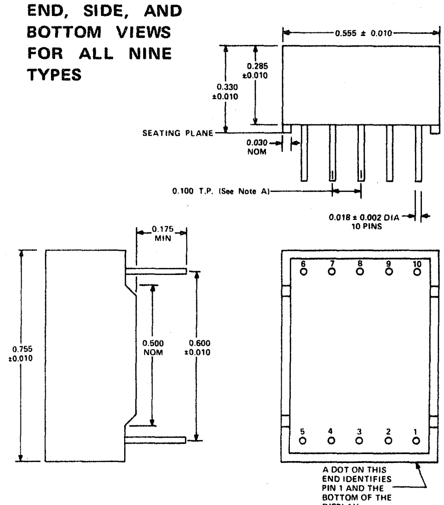
TIL321 THRU TIL326



TIL330, TIL331, TIL332



END, SIDE, AND BOTTOM VIEWS FOR ALL NINE TYPES



TIL321
TIL323
TIL325

PIN 1 CATHODE E
PIN 2 CATHODE D
PIN 3 ANODE: DIGIT & DECIMAL
PIN 4 CATHODE C
PIN 5 CATHODE DECIMAL
PIN 6 CATHODE B
PIN 7 CATHODE A
PIN 8 ANODE: DIGIT & DECIMAL
PIN 9 CATHODE F
PIN 10 CATHODE G

TIL322
TIL324
TIL326

PIN 1 ANODE E
PIN 2 ANODE D
PIN 3 CATHODE: DIGIT & DECIMAL
PIN 4 ANODE C
PIN 5 ANODE DECIMAL
PIN 6 ANODE B
PIN 7 ANODE A
PIN 8 CATHODE: DIGIT & DECIMAL
PIN 9 ANODE F
PIN 10 ANODE G

TIL330
TIL331
TIL332

PIN 1 CATHODE J
PIN 2 NO INTERNAL CONNECTION
PIN 3 ANODE: PLUS/MINUS ONE & DECIMAL
PIN 4 CATHODE C
PIN 5 CATHODE DECIMAL
PIN 6 CATHODE B
PIN 7 NO INTERNAL CONNECTION
PIN 8 ANODE: PLUS/MINUS ONE & DECIMAL
PIN 9 CATHODE H
PIN 10 CATHODE G

NOTES: A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within 0.010 of its true longitudinal position relative to pins 3 and 8.
B. All dimensions associated with segments and decimal points are nominal.
C. All dimensions are in inches unless otherwise specified.

TEXAS INSTRUMENTS
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absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature, Each Segment or Decimal Point	3 V
Peak Forward Current at (or below) 25°C Free-Air Temperature, Each Segment or Decimal Point	200 mA
Average Forward Current at (or below) 25°C Free-Air Temperature (See Notes 1 and 2), Each Segment or Decimal Point	25 mA
Operating Free-Air Temperature Range	–25°C to 85°C
Storage Temperature Range	–25°C to 85°C
Lead Temperature 1/16 Inch Below Seating Plane for 5 Seconds	230°C

NOTES: 1. This average value applies for any 10-ms period.
2. Derate linearly to 10 mA at 85°C free-air temperature at the rate of 0.25 mA/°C.

operating characteristics of each segment or decimal point at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TIL321, TIL322 TIL330			TIL323, TIL324, TIL331			TIL325, TIL326 TIL332			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
I_V Luminous Intensity (See Note 3)	Average per Segment	$I_F = 20$ mA	240	600		150	320		150	340		μcd
	Decimal Point		95	240		60	130		60	135		μcd
Segment-to-Segment Luminous Intensity Ratio				1.5:1			1.5:1			1.5:1		
λp Wavelength at Peak Emission			640	655	680		565			590		nm
$\Delta\lambda$ Spectral Bandwidth				20			40			40		nm
V_F Static Forward Voltage				1.7	2		2.5	3.5		2.5	3.5	V
I_R Static Reverse Current		$V_R = 3$ V		10			10			10		μA

NOTE 3: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve. Segments H and J are totaled and considered as one segment for this parameter.

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TEXAS INSTRUMENTS
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BULLETIN NO. DL-S 7611498, MARCH 1972—REVISED MARCH 1976

SOLID-STATE MULTIPLE SEVEN-SEGMENT VISIBLE DISPLAY WITH RIGHT-HAND DECIMALS

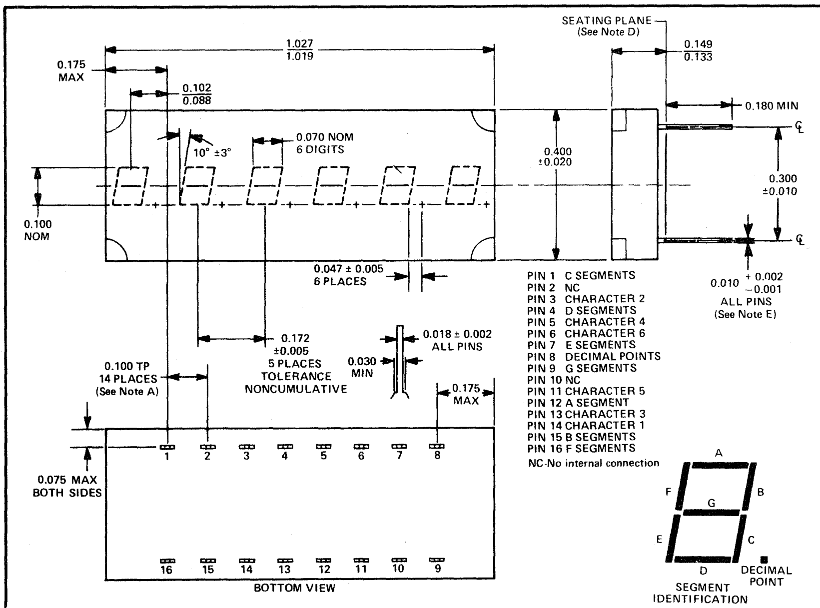
- 0.100-Inch Character Height
- High Luminous Intensity
- Low Power Requirements
- Wide Viewing Angle
- 0.172-Inch Character-to-Character Spacing, Constant with End-to-End Stacking of Devices

description

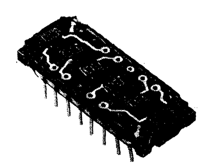
This multidigit display is intended for use under pulsed conditions by enabling each of the characters sequentially and enabling the desired segments and/or right-hand decimal point in phase with the character enabling pulse. The pulse rate is kept high enough so that to the eye the light from each character appears to be constant. Two or more of these devices may be stacked end-to-end to provide additional characters with constant spacing between characters. When additional characters are enabled by the same pulse sequence, the peak current in each segment or decimal may be increased to maintain character brightness despite the lower duty cycle for each character. The modifications shown in the product options section of this data sheet, are available to form various combinations.

mechanical data

The digit and decimal chips are mounted on a lead-frame assembly which is then cast within a red, electrically nonconductive, transparent plastic compound. Character-to-character spacing is maintained when multiple displays are mounted end-to-end.



NOTES:
- A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within 0.010 of its true longitudinal position relative to pins 1 and 16.
- B. Centerlines of character segments and decimal points are shown.
- C. The angle between the vertical axis of any digit and the vertical axis of the package is 10° ± 3°. The angle between the vertical axes of adjacent digits is a maximum of 4°.
- D. The maximum variation in vertical position is 0.010 inch between any two digits in the package and 0.005 inch between any two adjacent digits.
- E. Lead dimensions are not controlled above the seating plane.
- F. All dimensions are in inches unless otherwise specified.



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

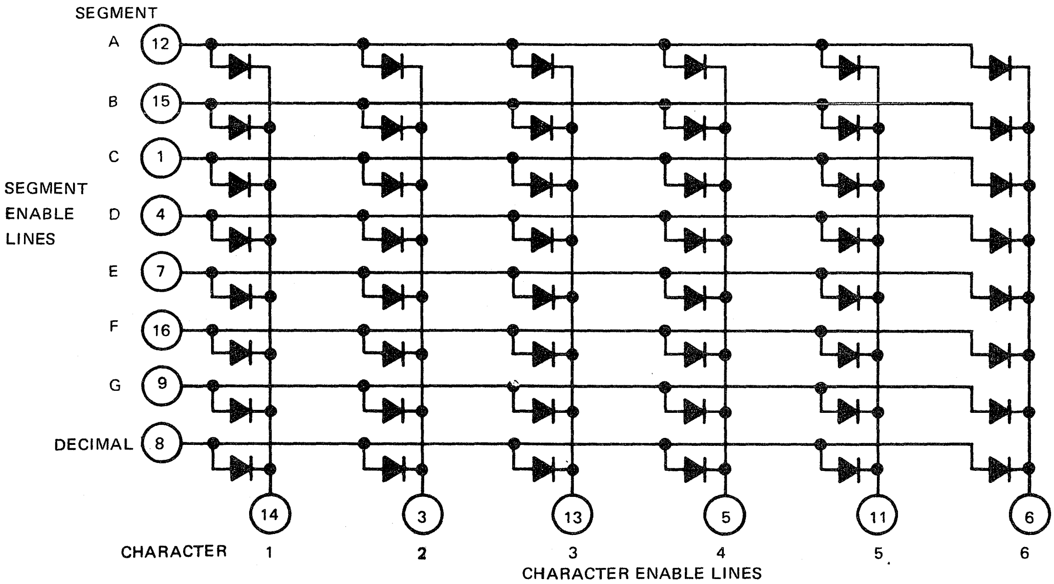
Reverse Voltage at 25°C Free-Air Temperature, Each Segment or Decimal Point	2 V
Peak Forward Current, Each Segment or Decimal Point (See Note 1)	150 mA
Average Forward Current, Each Segment or Decimal Point (See Note 2)	10 mA
Operating Free-Air Temperature Range	0°C to 70°C
Storage Temperature Range	−25°C to 85°C

operating characteristics of each segment or decimal at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V Luminous Intensity (See Note 3)	Segment	I_F = 10mA	48	96		μcd
	Decimal Point		42	84		μcd
λ_p Wavelength at Peak Emission			640	660	680	nm
$\Delta\lambda$ Spectral Bandwidth				20		nm
V_F Static Forward Voltage				1.65	2	V

NOTES: 1. This value applies for PRR ⩾ 100 Hz, duty cycle ⩽ 1/15.
2. This value applies for a maximum averaging time of 10 ms.
3. Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

schematic



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TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

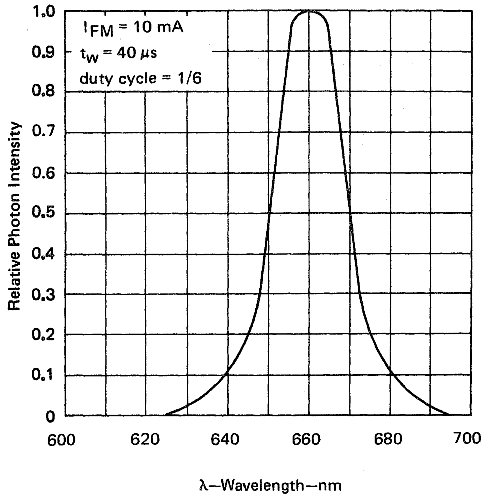

FIGURE 1

RELATIVE RADIANT INTENSITY
vs
FREE-AIR TEMPERATURE

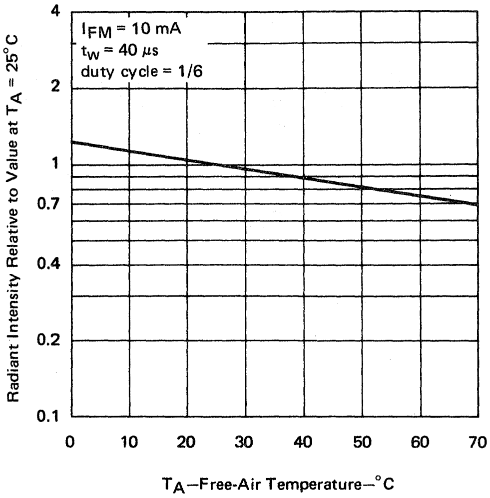

FIGURE 2

FORWARD CONDUCTION CHARACTERISTICS

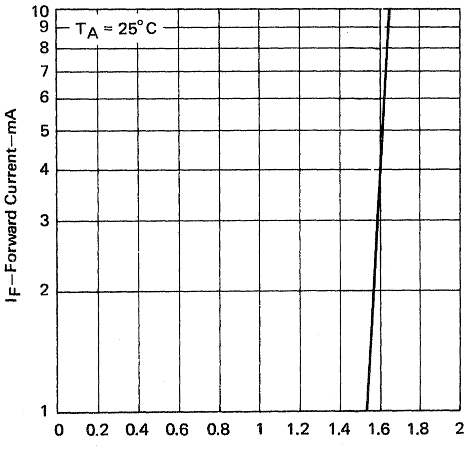

FIGURE 3

AVERAGE LUMINOUS INTENSITY (PER SEGMENT)
vs
PEAK FORWARD CURRENT

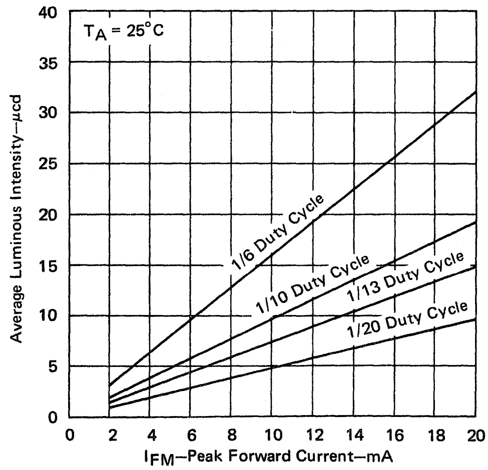

FIGURE 4

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PRODUCT OPTIONS

Texas Instruments can supply multidigit displays that are variations of the TIL360. These special devices can be arranged in various configurations, two of which are illustrated in Figures A and B. To describe the displays, digit positions are numbered 1 through 6, left to right.

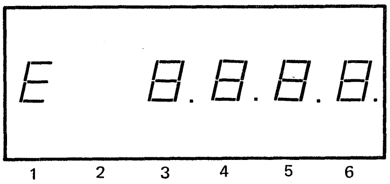


FIGURE A

In the device shown in Figure A, digit position number 1 is used for the special character E . This character forms the minus sign for negative quantities or an E to indicate an error condition. Digit position number 2 is not used and no connection should be made to pin 3.

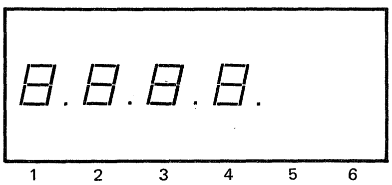


FIGURE B

In the device shown in Figure B, digit positions 5 and 6 are not used and no connections should be made to pins 6 and 11.

The TIL360 package is designed so that two or more displays can be mounted end-to-end maintaining the character-to-character dimension between digits. Two of many possible combinations are shown in Figure C and Figure D.

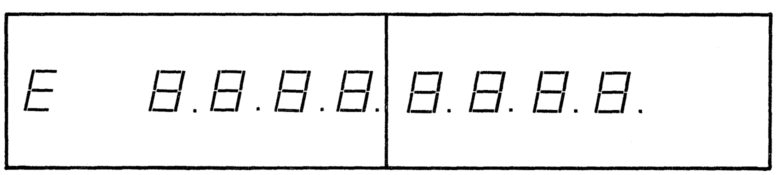


FIGURE C

Figure C illustrates the use of a pair of devices to display eight digits with E for minus sign and error indication.

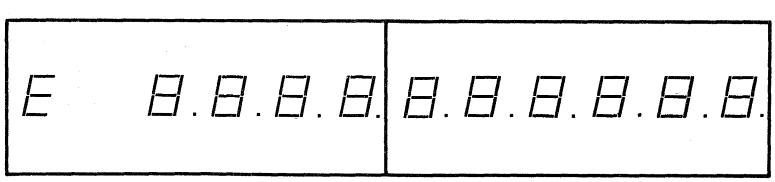


FIGURE D

Figure D illustrates the use of a pair of devices to display ten digits with E for minus sign and error indication.

In addition to the devices shown, other configurations are available on a contract basis.

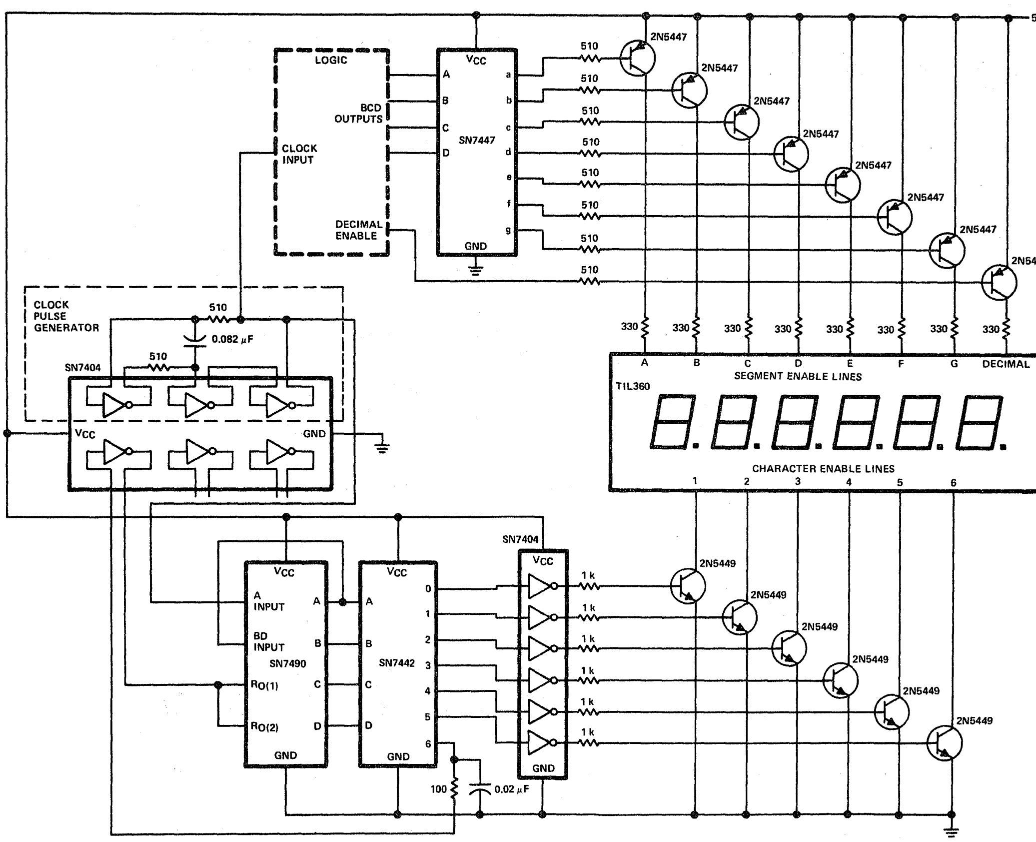
TYPICAL APPLICATION DATA

Figure E shows decoder driver circuitry that can interface the TIL360 six-digit display with TTL logic. It also shows a multiplex circuit used to turn each digit on in sequence at a one-sixth duty cycle.

The BCD code, generated by the user's specific logic circuitry and applied as input to the SN7447, will be decoded into a seven-segment output. This output drives p-n-p transistors which supply current to operate p-n junction segments of the display.

The 330-ohm resistor in series with each segment limits the peak current to nine milliamperes. The display brightness may be controlled by selection of the resistor value.

Multiplexing or strobing the digits sequentially is accomplished by use of the SN7490 counter and SN7442 4-to-10-line decoder. After counting to 6 the output from the SN7442 resets the SN7490 to zero, thus giving a duty cycle of one-sixth.



Resistor values are in ohms.

FIGURE E

TEXAS INSTRUMENTS INCORPORATED
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8

BULLETIN NO. DL-S 7612231, NOVEMBER 1974—REVISED MARCH 1976

TWO-DIGIT SOLID-STATE VISIBLE DISPLAYS WITH RED (TIL361), GREEN (TIL362), OR AMBER (TIL363) TRANSPARENT PLASTIC ENCAPSULATION

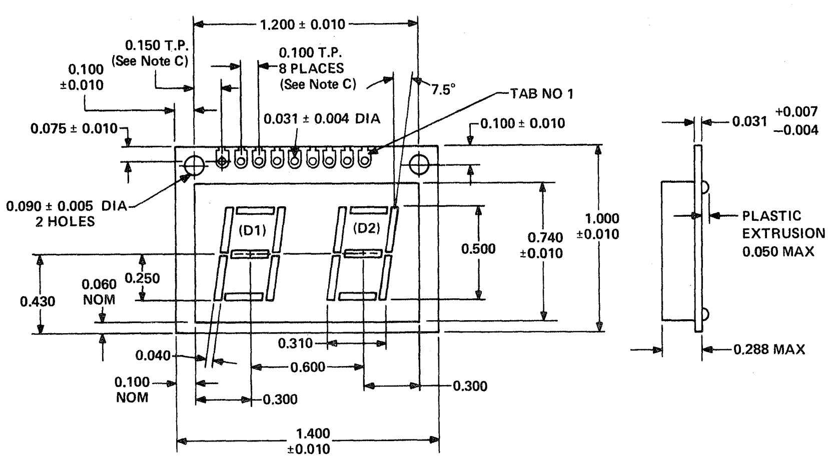
- 0.500-Inch-High Characters
- Continuous Uniform Segments
- Wide Viewing Angle
- High Contrast
- Low Power Requirements
- For TV Channel Indicator and Other 2-Digit Applications

description

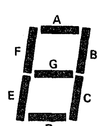
This multidigit display is intended for use under pulsed conditions by enabling each of the character cathodes sequentially and enabling the desired segments or indicator anodes in phase with the character enabling pulse. The pulse rate is kept high enough so that the light from each character appears to the eye to be constant.

mechanical data

The displays are formed by placing a one-piece reflector assembly within a transparent plastic case which is attached to a printed-circuit board that contains the light-emitting-diode chips. To optimize device performance, materials are used that are limited to certain solvents for cleaning operations. It is recommended that only freon TF, isopropanol, or water be used.

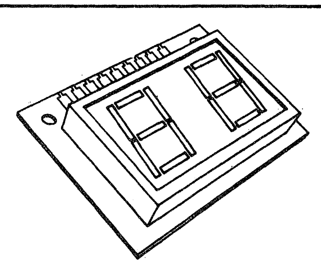


TAB 1 D-SEGMENT ANODES
TAB 2 A-SEGMENT ANODES
TAB 3 F-SEGMENT ANODES
TAB 4 E-SEGMENT ANODES
TAB 5 B-SEGMENT ANODES
TAB 6 C-SEGMENT ANODES
TAB 7 G-SEGMENT ANODES
TAB 8 DIGIT 1 CATHODES
TAB 9 DIGIT 2 CATHODES



SEGMENT IDENTIFICATION

NOTES: A. Dimensions associated with the digit segments, colon segments, alarm, indicator, and PM indicator are nominal.
B. All dimensions are in inches unless otherwise specified.
C. The true-position tab spacing is 0.100 between the centerlines. Each tab centerline is located within 0.010 of its true longitudinal position relative to the centerline of the left-hand mounting hole.



8

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature, Each Segment . . . . . . 3 V
Peak Forward Current at (or below) 25°C Free-Air Temperature,
Each Segment . . . . . . 200 mA
Average Forward Current at (or below) 25°C Free-Air Temperature (See Notes 1 and 2),
Each Segment . . . . . . 25 mA
Operating Free-Air Temperature Range . . . . . . −25°C to 85°C
Storage Temperature Range . . . . . . −25°C to 85°C
Terminal Temperature for 5 Seconds . . . . . . 230°C

NOTES: 1. This average value applies for any 10-ms period.
2. Derate linearly to 10 mA at 85°C free-air temperature at the rate of 0.25 mA/°C.

operating characteristics of each segment or decimal point at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TIL361			TIL362			TIL363			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
I_V	Luminous Intensity, Average per Segment, Each Digit (See Note 3)	I_F = 20 mA per segment	240	600		150	320		150	340		μcd
	Segment-to-Segment Luminous Intensity Ratio			1.5:1			1.5:1			1.5:1		
λ_p	Wavelength at Peak Emission		640	655	680		565			590		nm
$\Delta\lambda$	Spectral Bandwidth			20			40			40		nm
V_F	Static Forward Voltage			1.7	2.1		2.5	3.5		2.5	3.5	V

NOTE 3: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

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TEXAS INSTRUMENTS
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BULLETIN NO. DL-S 7612224, NOVEMBER 1974—REVISED MARCH 1976

4-DIGIT SOLID-STATE VISIBLE CLOCK DISPLAYS WITH RED, GREEN OR AMBER TRANSPARENT PLASTIC ENCAPSULATION

- 0.500-Inch-High Characters
- Continuous Uniform Segments
- Wide Viewing Angle
- High Contrast
- Low Power Requirements
- 24-Hour Displays Can Be Used in Timers (All 4 Digits Are Complete)

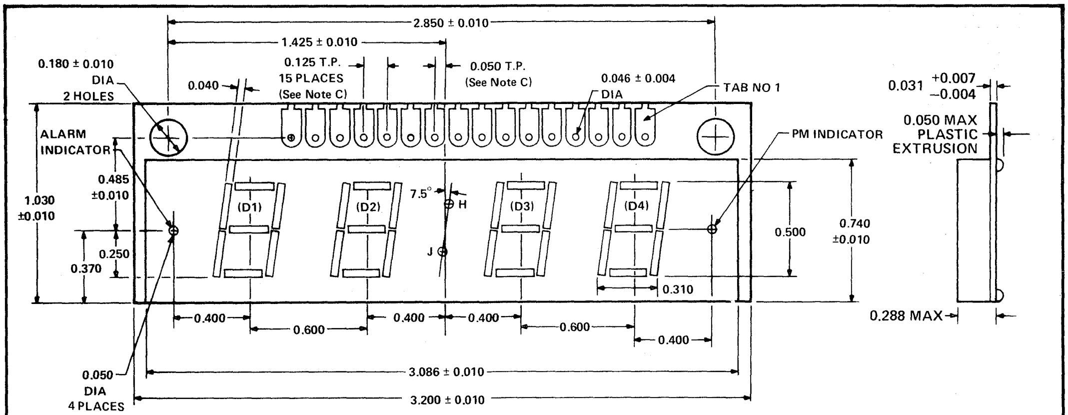
	12-HOUR DISPLAYS		24-HOUR DISPLAYS	
RED	TIL364	TIL367	TIL370	TIL373
GREEN	TIL365	TIL368	TIL371	TIL374
AMBER	TIL366	TIL369	TIL372	TIL375
SEGMENTS IN DIGIT 1	B & C*	B & C*	A–G	A–G
ALARM INDICATOR	yes	no*	yes	no*
PM INDICATOR	yes	yes	no*	no*

*Unused segments may or may not be omitted.

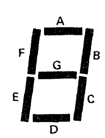
8

mechanical data

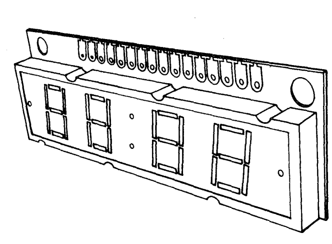
The displays are formed by placing a one-piece reflector assembly within a transparent plastic case which is attached to a printed-circuit board that contains the light-emitting-diode chips. To optimize device performance, materials are used that are limited to certain solvents for cleaning operations. It is recommended that only freon TF, isopropanol, or water be used.



TAB 1 PM-INDICATOR CATHODE
TAB 2 PM-INDICATOR ANODE
TAB 3 D-SEGMENT ANODES
TAB 4 C-SEGMENT ANODES
TAB 5 B-SEGMENT ANODES
TAB 6 A-SEGMENT ANODES
TAB 7 E-SEGMENT ANODES
TAB 8 F-SEGMENT ANODES
TAB 9 G-SEGMENT ANODES
TAB 10 DIGIT 1 & ALARM INDICATOR CATHODES
TAB 11 DIGIT 2 CATHODES
TAB 12 COLON SEGMENT H ANODE
TAB 13 COLON SEGMENT J ANODE
TAB 14 COLON SEGMENT H & DIGIT 4 CATHODE
TAB 15 ALARM INDICATOR ANODE
TAB 16 COLON SEGMENT J & DIGIT 3 CATHODE



SEGMENT IDENTIFICATION



NOTES: A. Dimensions associated with the digit segments, colon segments, alarm indicator, and PM indicator are nominal.
B. All dimensions are in inches unless otherwise specified.
C. The true-position tab spacing is 0.125 between centerlines. Each tab centerline is located within 0.010 of its true position relative to the vertical centerline of the device.

description

This multidigit display is intended for use under pulsed conditions by enabling each of the character cathodes sequentially and enabling the desired segments or indicator anodes in phase with the character-enabling pulse. The pulse rate is kept high enough so that the light from each character appears to the eye to be constant.

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature, Each Segment or Indicator . . . . 3 V
Peak Forward Current at (or below) 25°C Free-Air Temperature,
Each Segment or Indicator . . . . 200 mA
Average Forward Current at (or below) 25°C Free-Air Temperature (See Notes 1 and 2),
Each Segment or Indicator . . . . 25 mA
Operating Free-Air Temperature Range . . . . −25°C to 85°C
Storage Temperature Range . . . . −25°C to 85°C
Terminal Temperature for 5 Seconds . . . . 230°C

NOTES: 1. This average value applies for any 10-ms period.
2. Derate linearly to 10 mA at 85°C free-air temperature at the rate of 0.25 mA/°C.

operating characteristics of each segment or indicator at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	TIL364, TIL367 TIL370, TIL373			TIL365, TIL368 TIL371, TIL374			TIL366, TIL369 TIL372, TIL375			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
I_V Luminous Intensity (See Note 3)	Average per Segment, Each Digit	I_F = 20 mA per segment and indicator	240	600		150	320		150	340		μcd
	Each Colon Segment and Indicator		95	240		60	130		60	135		μcd
Segment-to-Segment Luminous Intensity Ratio				1.5:1			1.5:1			1.5:1		
λ_p Wavelength at Peak Emission			640	655	680		565			590		nm
$\Delta\lambda$ Spectral Bandwidth				20			40			40		nm
V_F Static Forward Voltage				1.7	2.1		2.5	3.5		2.5	3.5	V

NOTE 3: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

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TEXAS INSTRUMENTS
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BULLETIN NO. DL-S 7512329, NOVEMBER 1975

SOLID-STATE RED DISPLAY FOR CALCULATOR APPLICATIONS

- **0.106-Inch Magnified Image, Clear Lens**
- **Seven-Segment Digits, Right-Hand Decimal Points**
- **Uniform Brightness and Digit Alignment**
- **0.175-Inch Digit-to-Digit Spacing**
- **Wide Viewing Angle**

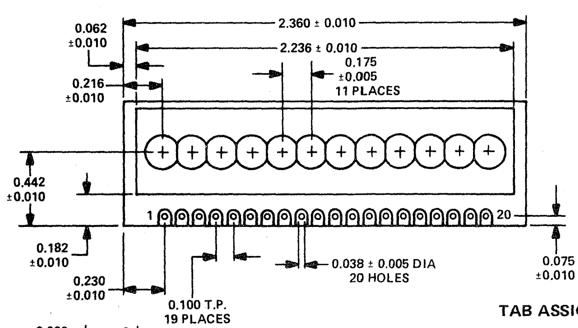
8

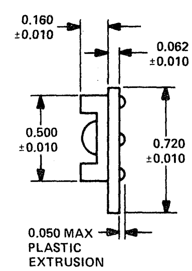
mechanical data

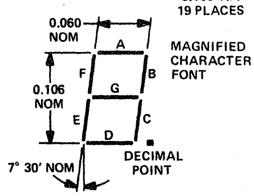
The GaAsP monolithic chips (one for each digit) are mounted on a printed-circuit board. A clear plastic lens is attached to the p-c board providing protection for the chips and resulting in a magnified digit image of 0.106 inch.

The display may be mounted by use of a lead-frame assembly on 0.100-inch centers with the pins soldered into the p-c board holes, or by insertion into a p-c board edge connector. A rosin-core 60/40 tin/lead wire solder or a low-temperature deactivating flux with solid-core 60/40 solder can be used for hand-soldering operations.

Clorinated hydrocarbon solvents must not be used for cleaning as the plastic lens may be damaged. Methanol, isopropanol, ethanol, Freon TP-35, or Freon TE-35 solvents may be used with caution. Time must be allowed for the solvent to evaporate from beneath the display lens.







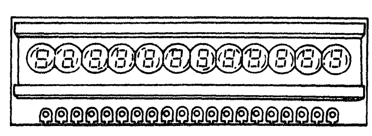
TOTAL VIEWING ANGLE (See Note C)

Horizontal 30°

Vertical 36°

TAB ASSIGNMENTS

TAB	FUNCTION	TAB	FUNCTION
1	SEGMENT A ANODES	11	DIGIT 4 CATHODE
2	SEGMENT F ANODES	12	DIGIT 1 CATHODE
3	SEGMENT B ANODES	13	DIGIT 5 CATHODE
4	SEGMENT C ANODES	14	DIGIT 12 CATHODE
5	SEGMENT D ANODES	15	DIGIT 6 CATHODE
6	DECIMAL POINT ANODES	16	DIGIT 11 CATHODE
7	SEGMENT E ANODES	17	DIGIT 7 CATHODE
8	SEGMENT G ANODES	18	DIGIT 10 CATHODE
9	DIGIT 3 CATHODE	19	DIGIT 9 CATHODE
10	DIGIT 2 CATHODE	20	DIGIT 8 CATHODE



NOTES: A. The true-position tab spacing is 0.100 between centerlines. Each tab centerline is located within 0.010 of its true position relative to tab 1.
B. All dimensions are in inches unless otherwise noted.
C. Total viewing angle is the angle that encompasses all the lines of sight along which the digit is legible within a given plane.

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

description

This multidigit display is intended for use under pulsed conditions by enabling the common cathode of each digit sequentially and enabling the desired segment anode and/or right-hand decimal point anode in phase with the character-enabling pulse. The pulse rate is kept high enough so that the light from each character appears to the eye to be constant.

absolute maximum ratings over operating free-air temperature range

Reverse Voltage, Each Segment or Decimal Point . . . . 3 V
Peak Forward Current, Each Segment or Decimal Point . . . . 60 mA
Average Forward Current, Each Segment or Decimal Point (See Note 1) . . . . 5 mA
Operating Free-Air Temperature Range . . . . −25°C to 85°C
Storage Temperature Range . . . . −25°C to 85°C
Terminal Temperature for 5 Seconds . . . . 230°C

NOTE 1: This average value applies for any 10-ms period.

operating characteristics of each segment or decimal at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{v(pk)}$	Peak Luminous Intensity (See Note 2)	Segment	I_{FM} = 10 mA, t_w = 5 ms, PRR = 100 Hz	200	600		μcd
		Decimal		200	600		
λ_p	Wavelength at Peak Emission			640	660	680	nm
$\Delta\lambda$	Spectral Bandwidth				20		nm
V_{FM}	Peak Forward Voltage				1.7	2.1	V

NOTE 2: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

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TEXAS INSTRUMENTS
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SOLID-STATE RED DISPLAYS FOR CALCULATOR APPLICATIONS

- **0.110-Inch Magnified Image**
- **Seven-Segment Digits, Right-Hand Decimal Points**
- **Common-Cathode Configuration for Multiplex Applications**
- **0.200-Inch Digit-to-Digit Spacing**

TYPE	NUMBER OF DIGITS
TIL380-8	8
TIL380-9	9

description

These multidigit displays are intended for use under pulsed conditions by enabling the common cathode of each digit sequentially and enabling the desired segment anode and/or right-hand decimal point anode in phase with the character-enabling pulse. The pulse rate is kept high enough so that the light from each character appears to the eye to be constant.

absolute maximum ratings over operating free-air temperature range

Reverse Voltage, Each Segment or Decimal Point	3 V
Peak Forward Current, Each Segment or Decimal Point	60 mA
Average Forward Current, Each Segment or Decimal Point (See Note 1)	5 mA
Operating Free-Air Temperature Range	−25°C to 85°C
Storage Temperature Range	−25°C to 85°C
Terminal Temperature for 5 Seconds	230°C

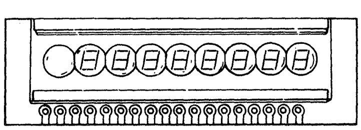
NOTE 1: This average value applies for any 10-ms period.

operating characteristics of each segment or decimal at 25°C free-air temperature

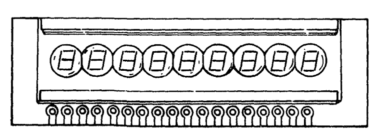
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{v(pk)}$ Peak Luminous Intensity (See Note 2)	Segment	I_{FM} = 10 mA, t_w = 5 ms, PRR = 100 Hz	200	600		μcd
	Decimal		200	600		μcd
λ_p Wavelength at Peak Emission			640	660	680	nm
$\Delta\lambda$ Spectral Bandwidth				20		nm
V_{FM} Peak Forward Voltage				1.7	2.1	V

NOTE 2: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

TIL380-8



TIL380-9



8

TEXAS INSTRUMENTS
INCORPORATED
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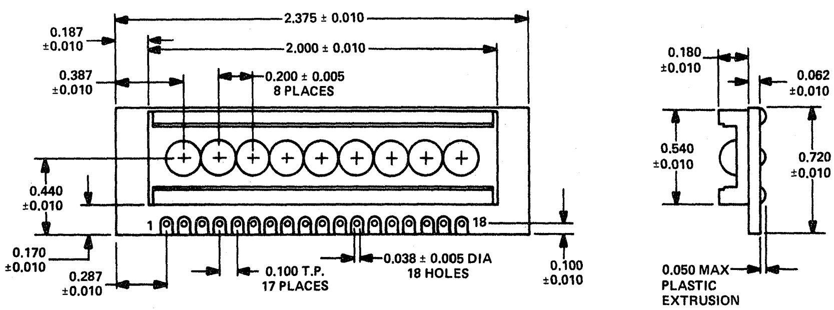
mechanical data

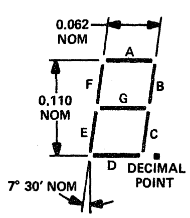
The GaAsP monolithic chips (one for each digit) are mounted on a printed-circuit board. A clear plastic lens is attached to the p-c board providing protection for the chips and resulting in a magnified digit image of 0.110 inch. The same lens is used for both types.

The display may be mounted by use of a lead-frame assembly on 0.100-inch centers with the pins soldered into the p-c board holes, or by insertion into a p-c board edge connector. A rosin-core 60/40 tin/lead wire solder or a low-temperature deactivating flux with solid-core 60/40 solder can be used for hand-soldering operations.

Clorinated hydrocarbon solvents must not be used for cleaning as the plastic lens may be damaged. Methanol, isopropanol, ethanol, Freon TP-35, or Freon TE-35 solvents may be used with caution. Time must be allowed for the solvent to evaporate from beneath the display lens.



MAGNIFIED
CHARACTER FONT



TOTAL VIEWING ANGLE (See Note C)

Horizontal 38° NOM
Vertical 38° NOM

TAB ASSIGNMENTS

TAB	FUNCTION
1	NO INTERNAL CONNECTION
2	DIGIT 1 CATHODE†
3	SEGMENT C ANODES
4	DIGIT 2 CATHODE
5	DECIMAL POINT ANODES
6	DIGIT 3 CATHODE
7	SEGMENT A ANODES
8	DIGIT 4 CATHODE
9	SEGMENT E ANODES
10	DIGIT 5 CATHODE
11	SEGMENT D ANODES
12	DIGIT 6 CATHODE
13	SEGMENT G ANODES
14	DIGIT 7 CATHODE
15	SEGMENT B ANODES
16	DIGIT 8 CATHODE
17	SEGMENT F ANODES
18	DIGIT 9 CATHODE

†Make no external connection to tab 2 of TIL380-8.

NOTES: A. The true-position tab spacing is 0.100 between centerlines. Each tab centerline is located within 0.010 of its true position relative to tab 1.
B. All dimensions are in inches unless otherwise noted.
C. Total viewing angle is the angle that encompasses all the lines of sight along which the digit is legible within a given plane.

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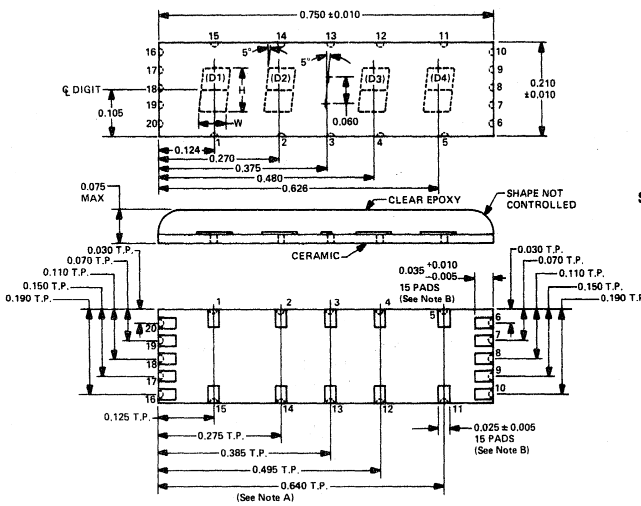
BULLETIN NO. DL-S 7512335, NOVEMBER 1975

FOUR-DIGIT SOLID-STATE VISIBLE DISPLAYS

- **0.100-Inch-High Digits (TIL382, TIL383)**
  0.116-Inch-High Digits (TIL384, TIL385)
- **Small Package Size (0.75 In by 0.21 In) and Low Power Requirements for Use in Watches**
- **Continuous Uniform Segments**
- **High Brightness**

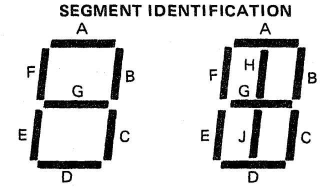
mechanical

The package consists of the digit and colon chips mounted on a dark ceramic substrate 0.750 inch long by 0.210 inch wide. The overall thickness of the package is 0.075 inch maximum after the top surfaces of the ceramic and the chips have been protected with a clear plastic compound. The terminal pads have a minimum plating thickness of 50 microinches of gold and may be attached to mother boards or other metal pads by conductive epoxy, reflow soldering, or solder paste. Chlorothane NU, isopropyl alcohol, freon TF, or water at 45°C may be used to remove flux and to clean the surfaces of the package.



NOTES: A. Each pad centerline is located within 0.010 of its true position.
B. Pad size is not controlled for pads 1, 2, 3, 4, and 5.
C. Dimensions associated with digit segments and colon segments are nominal.
D. Displays may be supplied with or without grooves at each pad at the option of TI.
E. All dimensions are in inches unless otherwise indicated.

SEGMENT IDENTIFICATION



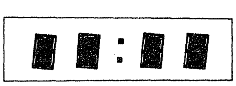
SEVEN-SEGMENT DIGIT NINE-SEGMENT DIGIT

TYPE	SEGMENTS PER DIGIT		DIMENSIONS OF DIGITS	
	D1, D2	D3, D4	W	H
TIL382	7	7	0.060	0.100
TIL383	9	7	0.060	0.100
TIL384	7	7	0.072	0.116
TIL385	9	7	0.072	0.116

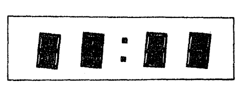
PAD 1 NC
PAD 2 NC
PAD 3 NC
PAD 4 NC
PAD 5 NC
PAD 6 D-SEGMENT ANODES
PAD 7 COLON ANODES
PAD 8 C-SEGMENT ANODES
PAD 9 B-SEGMENT ANODES
PAD 10 A-SEGMENT ANODES
PAD 11 DIGIT 4 CATHODES
PAD 12 DIGIT 3 CATHODES
PAD 13 COLON CATHODES
PAD 14 DIGIT 2 CATHODES
PAD 15 DIGIT 1 CATHODES
PAD 16 H-SEGMENT ANODES†
PAD 17 F-SEGMENT ANODES
PAD 18 G-SEGMENT ANODES
PAD 19 E-SEGMENT ANODES
PAD 20 J-SEGMENT ANODES†

NC—No internal connection
†Make no external connection to pads 16 and 20 of TIL382 and TIL384.

TIL382, TIL384



TIL383, TIL385



SHOWN TWO TIMES ACTUAL SIZE

8

1175

description

The TIL382 through TIL385 are four-digit high-brightness gallium arsenide phosphide light-emitting-diode displays designed for use in digital timepieces such as watches and clocks. Hours and minutes are displayed by two pairs of digits separated by a colon. The TIL382 and TIL384 have seven-segment numerical digits with all digits complete so they may be used in timers or in 24-hour clocks. The TIL383 and TIL385 feature nine-segment digits permitting a two-character day-of-the-week display. The eighth and ninth segments (H and J) are connected on only the first two digits.

The displays are designed to be operated with a peak current of ten milliamperes per segment at one-fourth duty cycle with a pulse rate high enough so that the light appears to be constant. Other conditions may be used as long as maximum ratings are not exceeded. Since the two colon dots are wired in parallel, the colon must be driven at either twice the current or half the duty cycle to measure the same brightness as the digit segments. This is, however, a matter of preference and may be adjusted to provide either nominally brighter or nominally dimmer colons.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Reverse Voltage at 25°C Free-Air Temperature, Each Segment or Colon Dot	5 V
Peak Forward Current, Each Segment or Colon Dot	100 mA
Average Forward Current, Each Segment or Colon Dot (See Note 1)	10 mA
Operating Free-Air Temperature Range	−10°C to 70°C
Storage Temperature Range	−10°C to 70°C
Terminal Temperature for 5 Seconds	210°C

NOTE 1: This average value applies for any 10-ms period.

operating characteristics of each segment or colon dot at 25°C free-air temperature

8

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V Luminous Intensity (See Note 2)		$I_F = 10$ mA	125			μcd
Luminous Intensity Ratio	Digit to Digit			1.3:1	1.7:1	
	Segment to Segment within a Digit			1.1:1	1.7:1	
	Colon to Colon			1.2:1	1.7:1	
	Average Colon to Average Segment		0.5:1	1:1	2:1	
λ_p Wavelength at Peak Emission			650	660	680	nm
$\Delta\lambda$ Spectral Bandwidth				40		nm
V_F Static Forward Voltage			1.4	1.6	1.9	V

NOTE 2: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

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TEXAS INSTRUMENTS
INCORPORATED
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SOLID-STATE RED DISPLAYS FOR CALCULATOR APPLICATIONS

- 0.102-Inch Magnified Image
- Seven-Segment Digits, Right-Hand Decimal Points
- Common-Cathode Configuration for Multiplex Applications
- 0.200-Inch Digit-to-Digit Spacing

TYPE	NUMBER OF DIGITS
TIL392-6	6
TIL392-8	8
TIL392-9	9

description

These multidigit displays are intended for use under pulsed conditions by enabling the common cathode of each digit sequentially and enabling the desired segment anode and/or right-hand decimal point anode in phase with the character-enabling pulse. The pulse rate is kept high enough so that the light from each character appears to the eye to be constant.

absolute maximum ratings over operating free-air temperature range

Reverse Voltage, Each Segment or Decimal Point	3 V
Peak Forward Current, Each Segment or Decimal Point	60 mA
Average Forward Current, Each Segment or Decimal Point (See Note 1)	5 mA
Operating Free-Air Temperature Range	−25°C to 85°C
Storage Temperature Range	−25°C to 85°C
Terminal Temperature for 5 Seconds	230°C

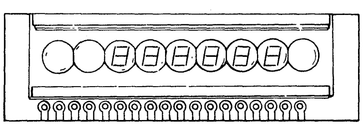
NOTE 1: This average value applies for any 10-ms period.

operating characteristics of each segment or decimal at 25°C free-air temperature

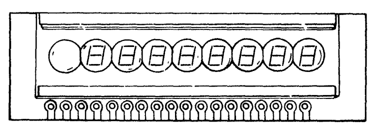
PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{v(pk)}$	Peak Luminous Intensity (See Note 2)	Segment	I_{FM} = 10 mA, t_w = 5 ms, PRR = 100 Hz	200	600		µcd
		Decimal		200	600		
λ_p	Wavelength at Peak Emission			640	660	680	nm
$\Delta\lambda$	Spectral Bandwidth				20		nm
V_{FM}	Peak Forward Voltage				1.7	2.1	V

NOTE 2: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

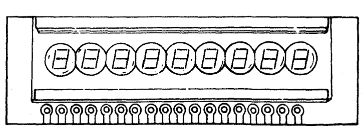
TIL392-6



TIL392-8



TIL392-9

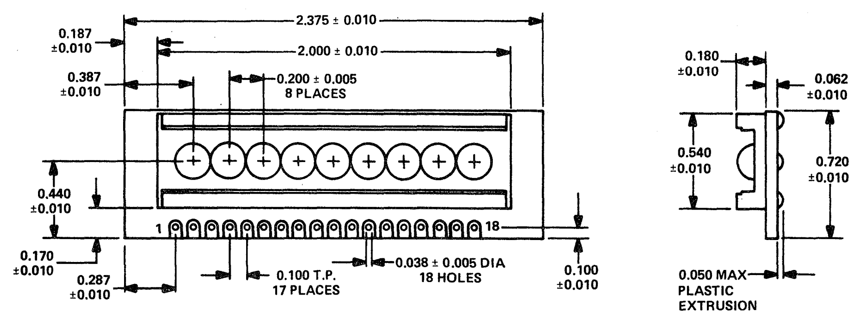


mechanical data

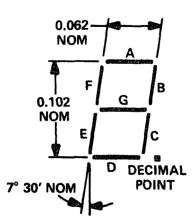
The GaAsP monolithic chips (one for each digit) are mounted on a printed-circuit board. A clear plastic lens is attached to the p-c board providing protection for the chips and resulting in a magnified digit image of 0.102 inch. The same lens is used for all three types.

The display may be mounted by use of a lead-frame assembly on 0.100-inch centers with the pins soldered into the p-c board holes, or by insertion into a p-c board edge connector. A rosin-core 60/40 tin/lead wire solder or a low-temperature deactivating flux with solid-core 60/40 solder can be used for hand-soldering operations.

Clorinated hydrocarbon solvents must not be used for cleaning as the plastic lens may be damaged. Methanol, isopropanol, ethanol, Freon TP-35, or Freon TE-35 solvents may be used with caution. Time must be allowed for the solvent to evaporate from beneath the display lens.



MAGNIFIED
CHARACTER FONT



TOTAL VIEWING ANGLE (See Note C)

Horizontal	36° NOM
Vertical	32° NOM

TAB ASSIGNMENTS

TAB	FUNCTION
1	NO INTERNAL CONNECTION
2	DIGIT 1 CATHODE†‡
3	SEGMENT C ANODES
4	DIGIT 2 CATHODE‡
5	DECIMAL POINT ANODES
6	DIGIT 3 CATHODE
7	SEGMENT A ANODES
8	DIGIT 4 CATHODE
9	SEGMENT E ANODES
10	DIGIT 5 CATHODE
11	SEGMENT D ANODES
12	DIGIT 6 CATHODE
13	SEGMENT G ANODES
14	DIGIT 7 CATHODE
15	SEGMENT B ANODES
16	DIGIT 8 CATHODE
17	SEGMENT F ANODES
18	DIGIT 9 CATHODE‡

†Make no external connection to tab 2 of TIL392-8.
‡Make no external connection to tab 2, 4, or 18 of TIL392-6.

NOTES: A. The true-position tab spacing is 0.100 between centerlines. Each tab centerline is located within 0.010 of its true position relative to tab 1.
B. All dimensions are in inches unless otherwise noted.
C. Total viewing angle is the angle that encompasses all the lines of sight along which the digit is legible within a given plane.

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BULLETIN NO. DL-S 7512355, DECEMBER 1975

SOLID-STATE RED DISPLAYS FOR CALCULATOR APPLICATIONS

- 0.102-Inch Magnified Image
- Seven-Segment Digits, Right-Hand Decimal Points
- Common-Cathode Configuration for Multiplex Applications
- 0.200-Inch Digit-to-Digit Spacing

TYPE	NUMBER OF DIGITS
TIL393-6	6
TIL393-8	8
TIL393-9	9

description

These multidigit displays are intended for use under pulsed conditions by enabling the common cathode of each digit sequentially and enabling the desired segment anode and/or right-hand decimal point anode in phase with the character-enabling pulse. The pulse rate is kept high enough so that the light from each character appears to the eye to be constant.

absolute maximum ratings over operating free-air temperature range

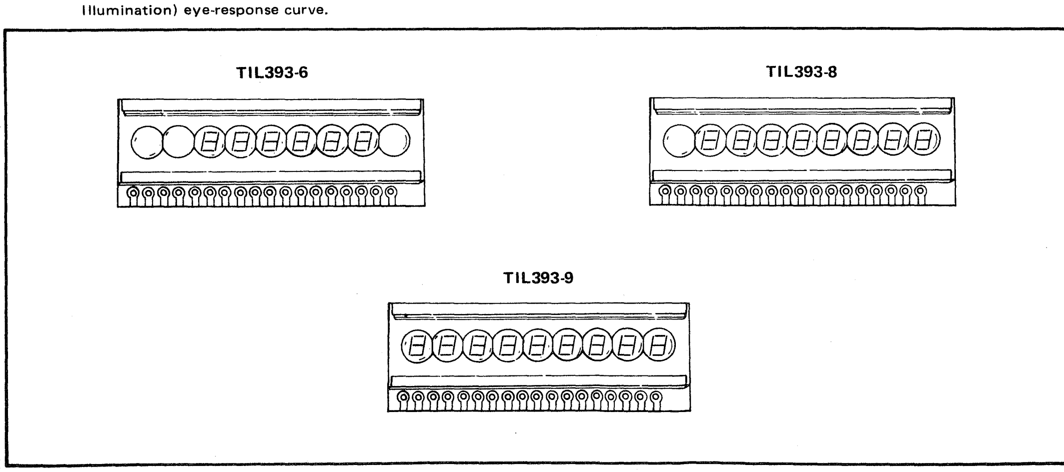
Reverse Voltage, Each Segment or Decimal Point	3 V
Peak Forward Current, Each Segment or Decimal Point	60 mA
Average Forward Current, Each Segment or Decimal Point (See Note 1)	5 mA
Operating Free-Air Temperature Range	−25°C to 85°C
Storage Temperature Range	−25°C to 85°C
Terminal Temperature for 5 Seconds	230°C

NOTE 1: This average value applies for any 10-ms period.

operating characteristics of each segment or decimal at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{v(pk)}$	Peak Luminous Intensity (See Note 2)	Segment	I_{FM} = 10 mA, t_w = 5 ms, PRR = 100 Hz	200	600		µcd
		Decimal		200	600		µcd
λ_p	Wavelength at Peak Emission			640	660	680	nm
$\Delta\lambda$	Spectral Bandwidth				20		nm
V_F	Static Forward Voltage				1.7	2.1	V

NOTE 2: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.



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INCORPORATED
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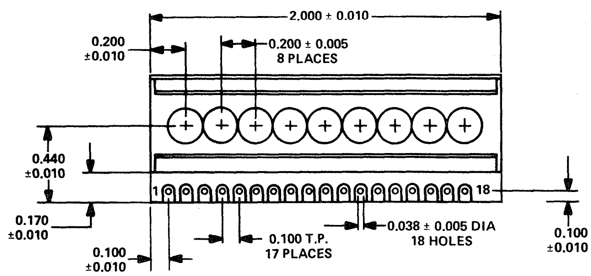
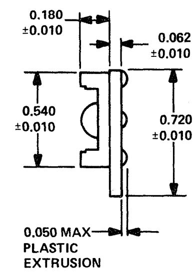
mechanical data

The GaAsP monolithic chips (one for each digit) are mounted on a printed-circuit board. A clear plastic lens is attached to the p-c board providing protection for the chips and resulting in a magnified digit image of 0.102 inch. The same lens is used for all three types.

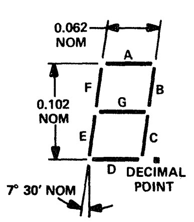
The display may be mounted by use of a lead-frame assembly on 0.100-inch centers with the pins soldered into the p-c board holes, or by insertion into a p-c board edge connector. A rosin-core 60/40 tin/lead wire solder or a low-temperature deactivating flux with solid-core 60/40 solder can be used for hand-soldering operations.

Clorinated hydrocarbon solvents must not be used for cleaning as the plastic lens may be damaged. Methanol, isopropanol, ethanol, Freon TP-35, or Freon TE-35 solvents may be used with caution. Time must be allowed for the solvent to evaporate from beneath the display lens.





MAGNIFIED CHARACTER FONT



TOTAL VIEWING ANGLE (See Note C)

Horizontal	36° NOM	
Vertical	32° NOM	

TAB ASSIGNMENTS

TAB	FUNCTION
1	NO INTERNAL CONNECTION
2	DIGIT 1 CATHODE†‡
3	SEGMENT C ANODES
4	DIGIT 2 CATHODE‡
5	DECIMAL POINT ANODES
6	DIGIT 3 CATHODE
7	SEGMENT A ANODES
8	DIGIT 4 CATHODE
9	SEGMENT E ANODES
10	DIGIT 5 CATHODE
11	SEGMENT D ANODES
12	DIGIT 6 CATHODE
13	SEGMENT G ANODES
14	DIGIT 7 CATHODE
15	SEGMENT B ANODES
16	DIGIT 8 CATHODE
17	SEGMENT F ANODES
18	DIGIT 9 CATHODE‡

†Make no external connection to tab 2 of TIL393-8.
‡Make no external connection to tab 2, 4, or 18 of TIL393-6.

NOTES: A. The true-position tab spacing is 0.100 between centerlines. Each tab centerline is located within 0.010 of its true position relative to tab 1.
B. All dimensions are in inches unless otherwise noted.
C. Total viewing angle is the angle that encompasses all the lines of sight along which the digit is legible within a given plane.

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TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES TIL394-8, TIL394-9
CALCULATOR NUMERIC DISPLAYS

BULLETIN NO. DL-S 7612357, DECEMBER 1975 – REVISED JANUARY 1976

SOLID-STATE RED DISPLAYS FOR CALCULATOR APPLICATIONS

- 0.110-Inch Magnified Image
- Seven-Segment Digits, Right-Hand Decimal Points
- Common-Cathode Configuration for Multiplex Applications
- 0.200-Inch Digit-to-Digit Spacing

TYPE	NUMBER OF DIGITS
TIL394-8	8
TIL394-9	9

description

These multidigit displays are intended for use under pulsed conditions by enabling the common cathode of each digit sequentially and enabling the desired segment anode and/or right-hand decimal point anode in phase with the character-enabling pulse. The pulse rate is kept high enough so that the light from each character appears to the eye to be constant.

absolute maximum ratings over operating free-air temperature range

Reverse Voltage, Each Segment or Decimal Point	3 V
Peak Forward Current, Each Segment or Decimal Point	60 mA
Average Forward Current, Each Segment or Decimal Point (See Note 1)	5 mA
Operating Free-Air Temperature Range	−25°C to 85°C
Storage Temperature Range	−25°C to 85°C
Terminal Temperature for 5 Seconds	230°C

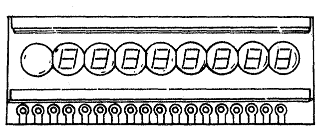
NOTE 1: This average value applies for any 10-ms period.

operating characteristics of each segment or decimal at 25°C free-air temperature

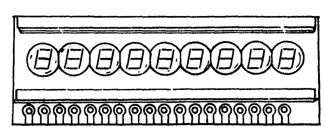
PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{v(pk)}$	Peak Luminous Intensity (See Note 2)	Segment	I_{FM} = 10 mA, t_w = 5 ms, PRR = 100 Hz	200	600		μcd
		Decimal		200	600		
λ_p	Wavelength at Peak Emission			640	660	680	nm
$\Delta\lambda$	Spectral Bandwidth				20		nm
V_{FM}	Peak Forward Voltage				1.7	2.1	V

NOTE 2: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

TIL394-8



TIL394-9

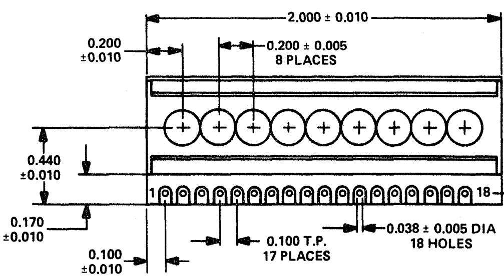


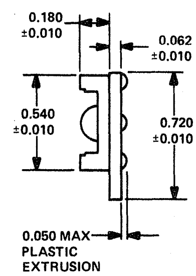
mechanical data

The GaAsP monolithic chips (one for each digit) are mounted on a printed-circuit board. A clear plastic lens is attached to the p-c board providing protection for the chips and resulting in a magnified digit image of 0.110 inch. The same lens is used for both types.

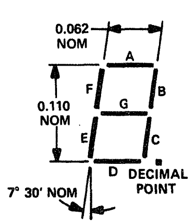
The display may be mounted by use of a lead-frame assembly on 0.100-inch centers with the pins soldered into the p-c board holes, or by insertion into a p-c board edge connector. A rosin-core 60/40 tin/lead wire solder or a low-temperature deactivating flux with solid-core 60/40 solder can be used for hand-soldering operations.

Clorinated hydrocarbon solvents must not be used for cleaning as the plastic lens may be damaged. Methanol, isopropanol, ethanol, Freon TP-35, or Freon TE-35 solvents may be used with caution. Time must be allowed for the solvent to evaporate from beneath the display lens.





MAGNIFIED
CHARACTER FONT



TOTAL VIEWING ANGLE (See Note C)

Horizontal	38° NOM
Vertical	38° NOM

TAB ASSIGNMENTS

TAB	FUNCTION
1	NO INTERNAL CONNECTION
2	DIGIT 1 CATHODE†
3	SEGMENT C ANODES
4	DIGIT 2 CATHODE
5	DECIMAL POINT ANODES
6	DIGIT 3 CATHODE
7	SEGMENT A ANODES
8	DIGIT 4 CATHODE
9	SEGMENT E ANODES
10	DIGIT 5 CATHODE
11	SEGMENT D ANODES
12	DIGIT 6 CATHODE
13	SEGMENT G ANODES
14	DIGIT 7 CATHODE
15	SEGMENT B ANODES
16	DIGIT 8 CATHODE
17	SEGMENT F ANODES
18	DIGIT 9 CATHODE

†Make no external connection to tab 2 of TIL394-8.

NOTES: A. The true-position tab spacing is 0.100 between centerlines. Each tab centerline is located within 0.010 of its true position relative to tab 1.
B. All dimensions are in inches unless otherwise noted.
C. Total viewing angle is the angle that encompasses all the lines of sight along which the digit is legible within a given plane.

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TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

BULLETIN NO. DL-S 7612372, MARCH 1976

FOUR-DIGIT SOLID-STATE VISIBLE DISPLAYS WITH MAGNIFICATION

- **0.100-Inch Magnified Image**
- **Small Package Size (0.75 In by 0.21 In) and Low Power Requirements for Use in Watches**
- **Continuous Uniform Segments**
- **High Brightness**

TYPE	SEGMENTS PER DIGIT		WITH COLON
	D1, D2	D3, D4	
TIL396	9	7	YES
TIL397	9	7	NO
TIL398	7	7	YES
TIL399	7	7	NO

description

The TIL396 through TIL399 are four-digit high-brightness gallium arsenide phosphide light-emitting-diode displays designed for use in digital timepieces such as watches and clocks. Hours and minutes are displayed by two pairs of digits. The TIL396 and TIL397 feature nine-segment digits permitting a two-character day-of-the-week display. The eighth and ninth segments (H and J) are connected on only the first two digits. The TIL398 and TIL399 have seven-segment numerical digits with all digits complete so they may be used in timers or in 24-hour clocks. The TIL396 and TIL398 can display a colon. The TIL397 and TIL399 have no colons.

The displays are designed to be operated with a peak current of ten milliamperes per segment at one-fourth duty cycle with a pulse rate high enough so that the light appears to be constant. Other conditions may be used as long as maximum ratings are not exceeded. Since the two colon dots are wired in parallel, the colon must be driven at either twice the current or half the duty cycle to measure the same brightness as the digit segments. This is, however, a matter of preference and may be adjusted to provide either nominally brighter or nominally dimmer colons.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Reverse Voltage at 25°C Free-Air Temperature, Each Segment or Colon Dot	5 V
Peak Forward Current, Each Segment or Colon Dot	100 mA
Average Forward Current, Each Segment or Colon Dot (See Note 1)	10 mA
Operating Free-Air Temperature Range	−10°C to 70°C
Storage Temperature Range	−10°C to 70°C
Terminal Temperature for 5 Seconds	210°C

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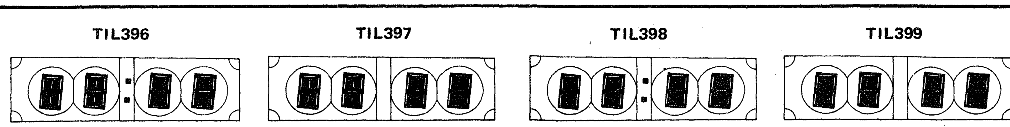
NOTE 1: This average value applies for any 10-ms period.

operating characteristics of each segment or colon dot at 25°C free-air temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V Luminous Intensity (See Note 2)		I_F = 10 mA	125			μcd
Luminous Intensity Ratio	Digit to Digit			1.3:1	1.7:1	
	Segment to Segment within a Digit			1.1:1	1.7:1	
	Colon to Colon			1.2:1	1.7:1	
	Average Colon to Average Segment		0.5:1	1:1	2:1	
λ_p Wavelength at Peak Emission			650	660	680	nm
$\Delta\lambda$ Spectral Bandwidth				40		nm
V_F Static Forward Voltage			1.4	1.7	2	V

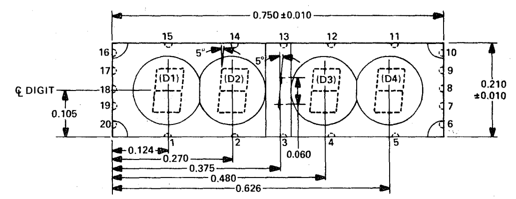
NOTE 2: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

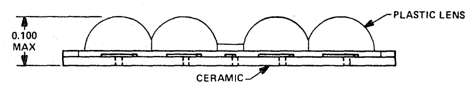


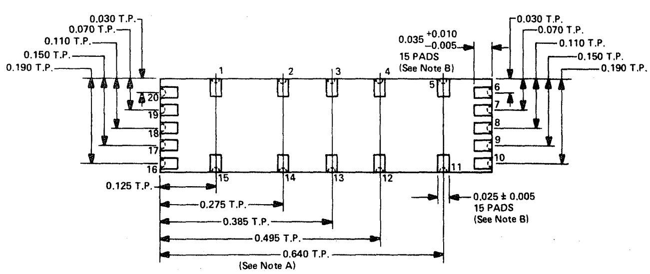
SHOWN TWO TIMES ACTUAL SIZE

mechanical

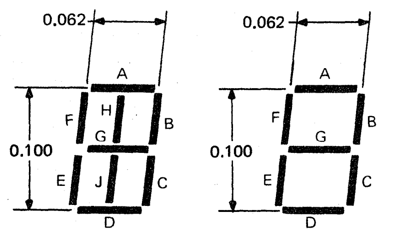
The package consists of the digit and colon chips mounted on a dark ceramic substrate 0.750 inch long by 0.210 inch wide. A clear plastic lens is attached to the substrate providing protection for the chips and resulting in a magnified digit image of 0.100 inch nominal. The terminal pads have a solderable plating and may be attached to mother boards or other metal pads by conductive epoxy, reflow soldering, or solder paste. Chlorothane NU, isopropyl alcohol, freon TF, or water at 45°C may be used to remove flux and to clean the surfaces of the package.







MAGNIFIED CHARACTER FONTS



NINE-SEGMENT DIGIT   SEVEN-SEGMENT DIGIT

PAD 1	NC
PAD 2	NC
PAD 3	NC
PAD 4	NC
PAD 5	NC
PAD 6	D-SEGMENT ANODES
PAD 7	COLON ANODES†
PAD 8	C-SEGMENT ANODES
PAD 9	B-SEGMENT ANODES
PAD 10	A-SEGMENT ANODES
PAD 11	DIGIT 4 CATHODES
PAD 12	DIGIT 3 CATHODES
PAD 13	COLON CATHODES†
PAD 14	DIGIT 2 CATHODES
PAD 15	DIGIT 1 CATHODES
PAD 16	H-SEGMENT ANODES‡
PAD 17	F-SEGMENT ANODES
PAD 18	G-SEGMENT ANODES
PAD 19	E-SEGMENT ANODES
PAD 20	J-SEGMENT ANODES‡

NC—No internal connection
†Make no external connection to pads 7 and 13 of TIL396 and TIL397.
‡Pads may or may not be present at pad locations 16 and 20 of the TIL398 and TIL399. If pads are present at these locations on the TIL398 and TIL399, make no external connections to them.

NOTES:
A. Each pad centerline is located within 0.010 of its true position.
B. Pad size is not controlled for pads 1, 2, 3, 4, and 5.
C. Dimensions associated with digit segments and colon segments are nominal.
D. Displays may be supplied with or without grooves at each pad at the option of TI.
E. All dimensions are in inches unless otherwise indicated.

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TEXAS INSTRUMENTS
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TIXL311 HEXADECIMAL LED DISPLAY

by Bruce E. Aldridge

The TIL311 is designed to store and display decimal and hexadecimal data. The device consists of an MSI logic chip to perform logic and storage functions plus a light emitting diode (LED) display in a single 14-pin dual in-line package.

It accepts parallel 8-4-2-1 data on four input lines and displays the corresponding decimal or hexadecimal character on a 4-by-7 dot matrix. Figure 1 illustrates the hexadecimal character representation for the decimal numbers 0 through 15. The logic levels are designed to be TTL compatible: a high level is 2 V to 5 V, a low level is 0 V to 0.8 V.

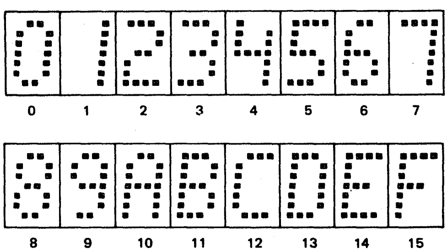

FIGURE 1. TIL311 Hexadecimal Character Configuration

The block diagram in Figure 2 shows the major sections of the TIL311; latches, decoder, current driver, and LED display. The inputs are DATA, LATCH STROBE, BLANKING, and DP. DATA is parallel 8-4-2-1 coded data. When LATCH STROBE is low, the data in the latches follow the data inputs. When LATCH STROBE goes high, the data on the input lines at strobe time is stored in the latches.

The 4-bit code is decoded and the required diodes are turned on via the constant-current drivers to display the proper character.

The LED display contains two decimal points: one to the left and one to the right of the character. A low input to one of the DP inputs will turn that decimal point on.

BLANKING must be low to display the character. When BLANKING goes high, the character is turned off regardless of the inputs. The BLANKING input does not change the data stored in the latches. BLANKING may be pulsed to intensity-modulate the display. The apparent brightness of the display is proportional to the duty cycle of the modulating signal, assuming a frequency high enough to avoid visible flicker. For example, at 1 kHz, a 50% duty

8

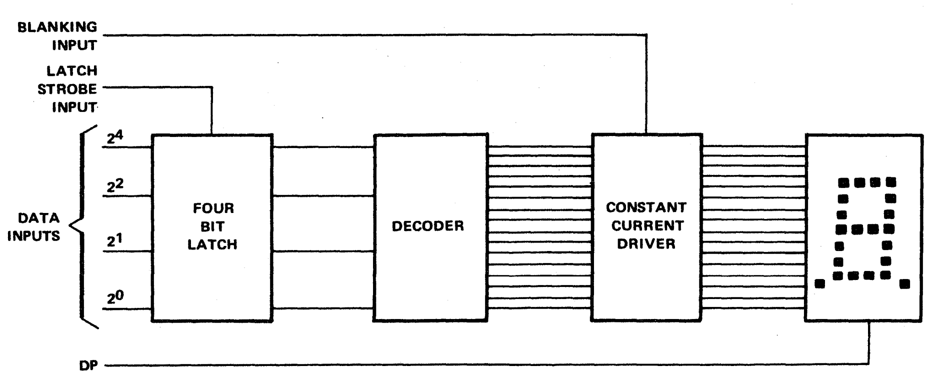

FIGURE 2. TIL311 Hexadecimal Display Block Diagram

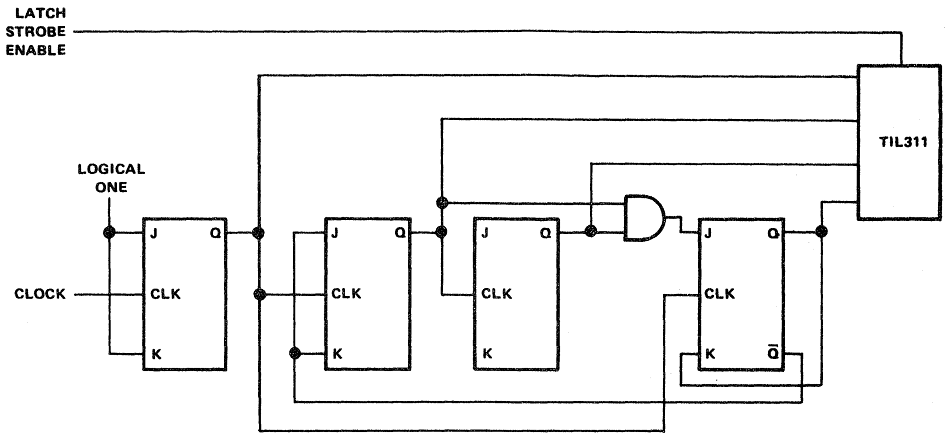

FIGURE 3. TIL311 Used As Counter Display

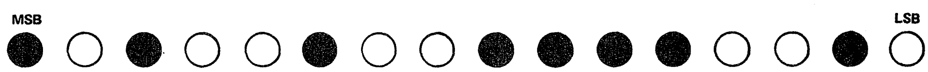

FIGURE 4. Discrete Light Display for a 16-Bit Register

8

cycle would cause an apparent brightness of 50% of the steady-state brightness.

Figure 3 illustrates the use of the TIL311 as a decimal display. The JK flip-flops are connected as a count-by-ten counter and represent one decade position in a multi-decade counter. The four Q outputs of the four flip-flops furnish the data inputs to the TIL311. Normally LATCH STROBE will be held high so that the display does not follow the counting. When counting is complete for a given time base, LATCH STROBE is pulsed with a negative-going pulse. The new data is then transferred from the decade counter into the latches and displayed.

Another application for the TIL311 is to display register information on computer control panels and service panels. Figure 4 illustrates the use of discrete lights to display the contents of a 16-bit register. The length of the display can easily lead to errors in interpretation of the data. Figure 5 illustrates the use of the TIL311 to display the same data in the same 16-bit register. The 16 register positions are divided into four 4-bit groups. The four bits in each group provide the inputs to each of four TIL311 displays. The resulting four hexadecimal character display provides a more concise interpretation of the register data.

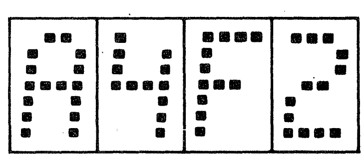

FIGURE 5. Hexadecimal Display for a 16-Bit Register

TEXAS INSTRUMENTS
INCORPORATED
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COUNTING CIRCUITS USING TIL306 AND TIL308 LEDs

by
Bert Kehren
and
Bruce Aldridge

Digital instruments have experienced a constant evolution since 1960. Counters that once occupied several inches of rack space in a 19-inch rack have been replaced by units the size of a text book with performance characteristics surpassing the older models. A major contribution to these changes is the continued advances in solid-state devices: integrated circuits have replaced the tubes and transistors and light-emitting diodes (LEDs) have replaced the incandescent displays.

Texas Instruments has introduced a new product that simplifies further the design of systems utilizing counters or digital read-outs. By combining an IC chip to perform the logic function and an LED display in a single 16-pin dual in-line package, Texas Instruments has provided the designer a device that reduces the complexity of his system without reducing flexibility of design. Two of these devices are the TIL306 and TIL308. The TIL306 and TIL308 have decimal points to the left side of the character. The TIL307 and TIL309 have decimal points to the right side of the character, but are otherwise identical to the TIL306 and TIL308, respectively. They can be combined to count, store, and display data in multiple decade positions.

CIRCUIT DESCRIPTION

The TIL306, as shown in Figure 1, consists of four major sections: counter, latches, decoder/driver, and LED display.

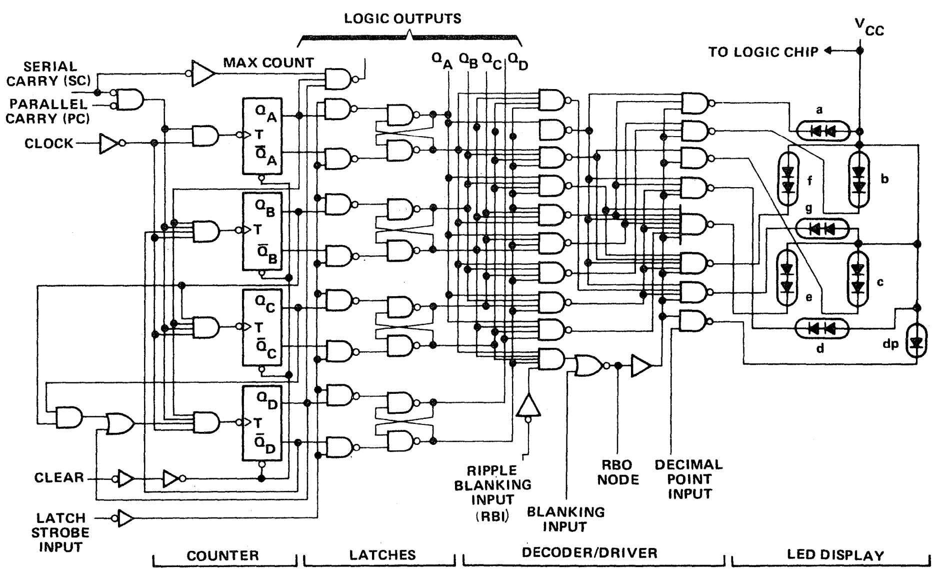


FIGURE 1. Functional Block Diagram of TIL306

The counter is connected as a synchronous counter. This configuration takes advantage of the minimal propogation delay to give maximum speed capability. Inputs to the counter are CLEAR, CLOCK, SERIAL CARRY, and PARALLEL CARRY. The counter and its inputs generate an output, MAX COUNT. Additional connections are LATCH STROBE, BLANKING, RIPPLE BLANKING, RBO, DECIMAL POINT and LOGIC OUTPUTS. All inputs and outputs are designed to be TTL compatible. A high level is a minimum of 2 V and a low level is a maximum of 0.8 V. A low input to CLEAR will reset the counter to zero independently of any other input. As long as the input remains low the counter remains at zero. A high is required to allow the counter to count.

The CLOCK input is the signal to be counted. With an input the counter will advance from 0 to 9. At a count of 9 the counter automatically resets to 0 with the next pulse. The counter changes state on the positive-going edge of the clock pulse. The clock pulse to the counter is controlled by SERIAL CARRY and PARALLEL CARRY.

The MAX COUNT output goes low when the counter reaches a count of 9, and then goes high when the counter progresses to 0 on the next clock input. This output can be connected to the CLOCK input of the next decade position for asynchronous operation or to the SERIAL CARRY input of the next decade position for synchronous operation.

A high on SERIAL CARRY inhibits the counter and forces MAX COUNT to go high regardless of the state of the counter stages. When SERIAL CARRY and PARALLEL CARRY go low, the CLOCK is enabled to the counter stages and the MAX COUNT gate is allowed to sense the status of the counter. The logic level of SERIAL CARRY must not be allowed to change while CLOCK is low or erroneous counts may result.

PARALLEL CARRY permits look ahead carry inputs from lower order decade positions. A high input inhibits the clock to the counter stages. When PARALLEL CARRY and SERIAL CARRY go low the clock to the counter stages is enabled. The logic level of PARALLEL CARRY must not be allowed to change while CLOCK is low or erroneous counts may result.

LATCH STROBE transfers the data in the counter stages to the latch storage to be displayed. With LATCH STROBE low, the latch flip-flops follow the states of the counter flip-flops. When LATCH STROBE goes high, the counter data is stored in the latch flip-flops. The counter can continue to count while the previous information is stored in the latches.

The DECIMAL POINT input controls the display of the decimal point. A high is required to turn on the LED decimal point display.

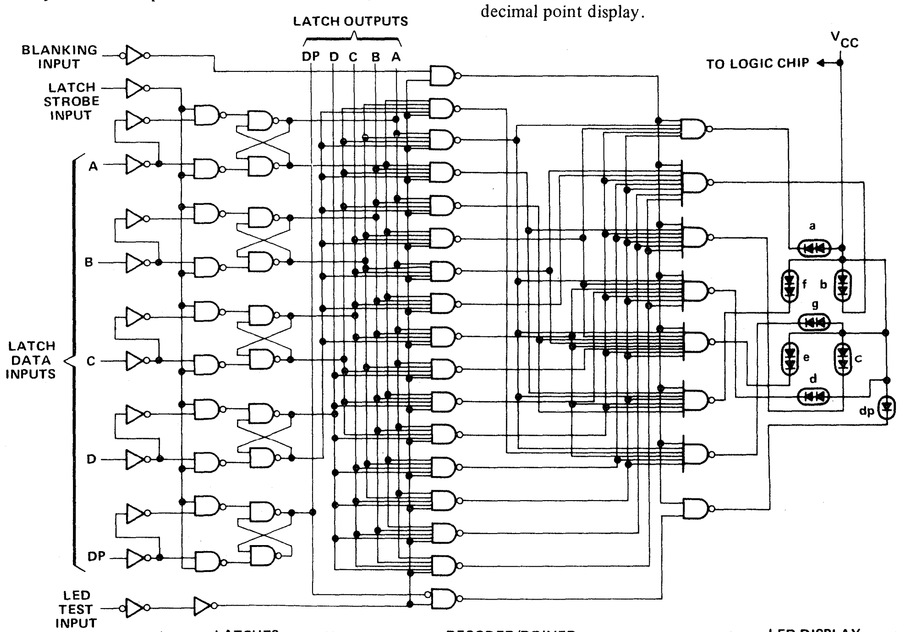


FIGURE 2. Functional Block Diagram of TIL308

A high on BLANKING inhibits the driver and gates and blanks the LED display. For normal operation, the BLANKING input must be low.

A low on RIPPLE BLANKING blanks the display if the latch flip-flops contain a count of zero. This combination also forces the RBO NODE to go low. By connecting the RBO NODE of one decade position to the RIPPLE BLANKING input of the next decade position, zero suppression can be achieved. This is discussed in detail in a later portion of this report, Counter Circuit Description. The RBO NODE has a resistor pullup, which allows this output to be used as an input. A low level applied to RBO will blank the LED display independently of other input.

The TIL308 looks physically identical to the TIL306. However, the TIL306 contains a counter section: the TIL308 does not. The TIL308 accepts 8-4-2-1 BCD code from external sources, stores it in latches, and displays the stored character by means of an LED display. As shown in Figure 2, the TIL308 consists of the three major sections: latch, decoder/driver, and LED display.

The inputs and outputs, designed to be TTL compatible, consist of DATA INPUTS, DATA OUTPUTS, LATCH STROBE, BLANKING, and LED TEST.

The BCD data and decimal point on the DATA INPUT lines are transferred into the latch flip-flops when LATCH STROBE is low. The BCD data and decimal point data stored in the latches are available at DATA OUTPUT. With LATCH STROBE high the DATA INPUT lines can change without effecting the data stored in the latches.

BLANKING must be high to display the data stored in the latches. When BLANKING goes low, the decoder drivers are inhibited and LED display is turned off. The data stored in the latches are not effected by BLANKING.

LED TEST can be used to test the LED display. A low to LED TEST will override all other signals and turn all of the LEDs on. LED TEST does not change the status of the latches.

With the basic operation of the circuits outlined, two typical interconnection methods are shown in Figure 3 and 4. Figure 3 shows the TIL306 connected in the synchronous mode. Figure 4 shows the TIL306 in the asynchronous mode. The asynchronous mode will be used in the following example of a counter.

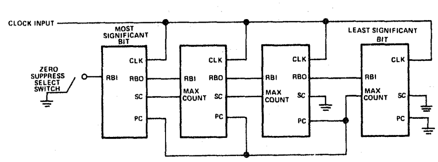


FIGURE 3. TIL306 Interconnections for Synchronous-Count Mode and High-Order-Zero Suppression.

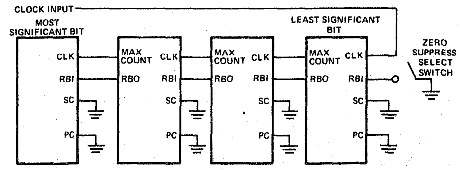


FIGURE 4. TIL306 Interconnections for Asynchronous-Counting Mode and Low-Order-Zero Suppression.

COUNTER CIRCUIT DESCRIPTION

The counter is a major constituent in digital instruments. Digital voltmeters, frequency counters, event counters, and period counters all have a circuit in common, very much like the one shown in Figure 4.

The circuit to be discussed in detail in this report incorporates both the TIL306 and the TIL308. One of the limiting factors of the TIL306 is that the counter typically does not count faster than 18 MHz. Combining the TIL306 with a TIL308 and feeding the TIL308 from a high-speed counter expands the system to a much higher frequency. Figure 5 shows a BCD counter capable of working at 100 MHz. The circuit consists of two SN74S112 Schottky

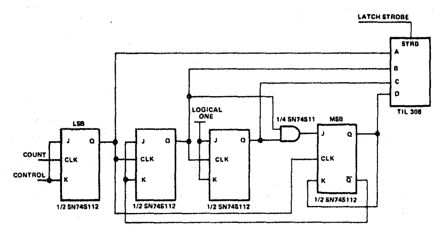


FIGURE 5. 100 MHz Decade Counter Using Texas Intruments Schottky TTL Logic and A TIL308 Display.

TTL circuits and one SN74S11 Schottky TTL circuit. This configuration results in an asynchronous BCD counter capable of dividing a 100-MHz signal down to 10 MHz. The speed is a result of Texas Instruments Schottky TTL devices that allow flip-flops to toggle in excess of 100 MHz. The Q outputs of the four flip-flops are fed into one TIL308, resulting in a decade with readout. The following decade position consists of a TIL306, which is capable of handling the 10 MHz rate. This circuit can be expanded even further by preceeding the Schottky counter stage with an ECL counter stage. ECL IC flip-flops with a 400-*MHz* toggle rate and discrete built ECL flip-flops with a toggle rate of 800 MHz are possible. Figure 6 shows a block diagram of a stage which is capable of counting up to 800 MHz. Since ECL levels do not coincide with TTL levels, an ECL-TTL converter is necessary. The output of the converter will drive the TIL308 without any interference caused by switching speed problems.

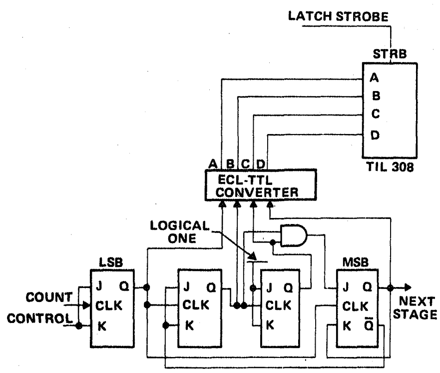


FIGURE 6. 800-MHz Decade Counter Using ECL Logic and A TIL308 Display.

TIL306 devices shows a big empty surface in the middle of the board and considerably fewer interconnects to the display. The cost savings resulting from using such a counter are quite obvious.

Figure 9 is a photo of a 100-MHz counter using seven TIL306 devices and two TIL308 devices. A compact assembly technique reduced the total size.

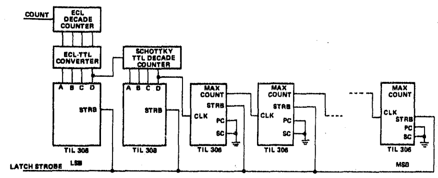
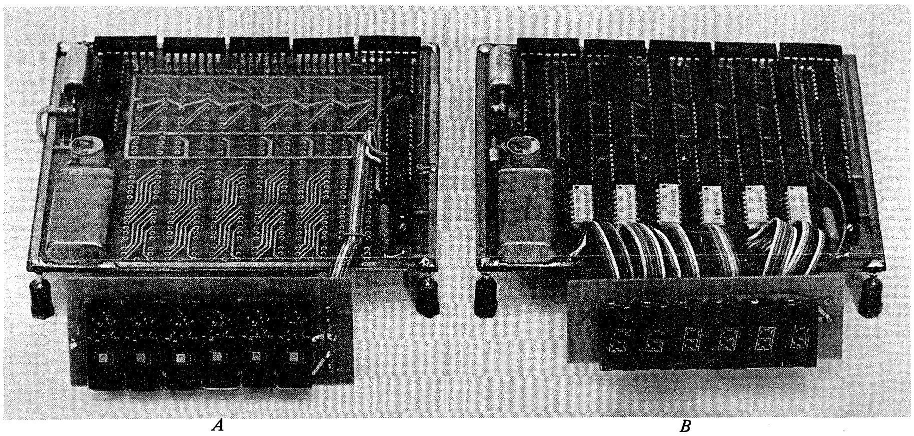


FIGURE 7. Nine-Digit Counter



A B

FIGURE 8. Two Counters with Identical Performance. Counter (A) Uses TIL306 Devices; Counter (B) Does not. Note how many less Components are Needed in the Counter Using TIL306 Devices.

Figure 7 is a block diagram representation of a nine-digit readout, consisting of an ECL decade counter with a TIL308 display and a Schottky TTL decade counter with a TIL308 display, as just described, and seven TIL306 devices. Part count is minimal, and the complexity of the PC Board is minimized.

Figure 8 is a photo of two counters with identical performance illustrating the difference in component count between a conventional counter consisting of SN7490, SN7475, and SN7447 TTL integrated circuits, resistors, with a display using TIL302 devices, and a counter using TIL306 devices. Both counters are specified to operate up to 15 MHz using a six-digit readout. The counter using

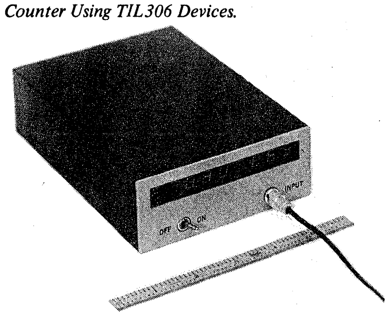


FIGURE 9. A Portable 100-MHz Counter Using Seven TIL306 Devices.

Figure 10 shows all of the basic circuit boards and components used in the counter shown in Figure 9 and shown schematically in Figure 12. The upper board is timebase. The center board is control. The bottom board is counter and display.

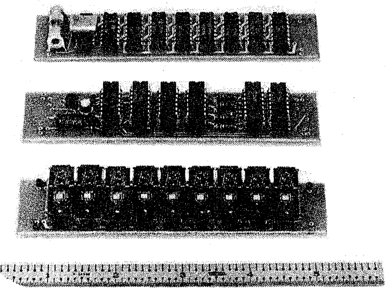


FIGURE 10. The Three Basic Circuit Boards of the Portable Counter.

in Figure 5 and seven TIL306 devices. This counter is capable of measuring frequencies up to 100 MHz and time with 10-nanosecond resolution. Again minimum part count and simplicity have been the major objectives. The unit is universal and the counter can be expanded into other functions by adding circuits to the basic building block.

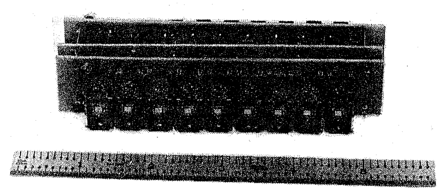


FIGURE 11. The Three Basic Circuit Boards Fastened Together into A Compact, High-Density Unit

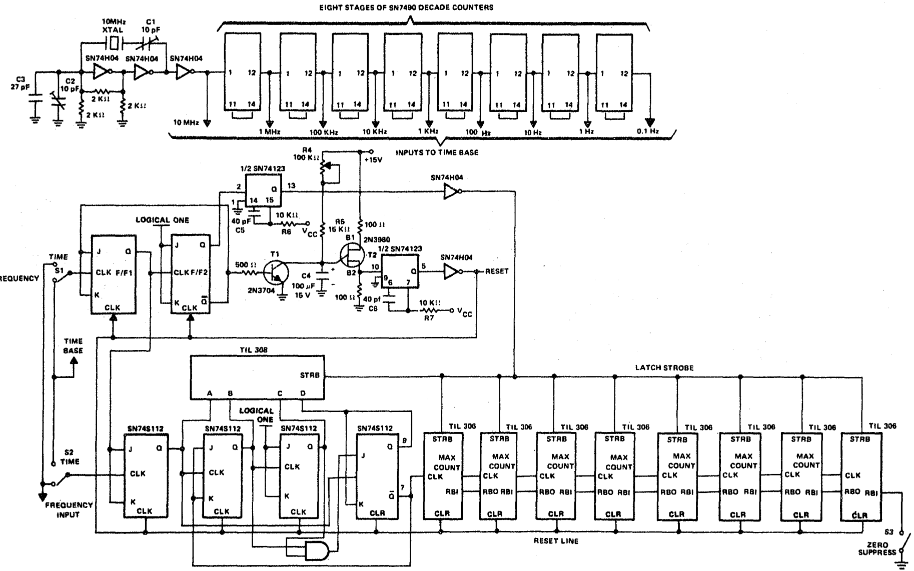


FIGURE 12. Schematic of A Frequency and Time Counter

Figure 11 shows the assembly technique for high density component packing. The total size is 1.2 inches high, 1.2 inches deep and 4.25 inches wide. This counter can be incorporated in a lightweight and portable instrument. Total power dissipation is 9 watts.

Figure 12 shows a complete schematic of a frequency and time counter incorporating the 100-MHz stage shown

The counter has three main functional sections: timebase, control, and counter.

The top part of Figure 12 is the time base. A 10-MHz oscillator is formed using two SN74H04 TTL high-speed inverters. The output is coupled through a third inverter to isolate the oscillator from the rest of the circuit. Capacitor C1 is a coarse adjust and capacitor C2 is a fine adjust. C2 should be a piston capacitor to allow finer resolution during adjustment. For more accurate requirements, a separate oscillator in a temperature-controlled oven with AGC circuitry can replace this circuit. The output of the oscillator is fed into a divider chain consisting of eight SN7490 decade dividers. Timing signals from 10 MHz to 0.1 Hz are generated and switch selectable as the time base. In the middle of the schematic in Figure 10 is the control circuit. The purpose of the control circuit is to gate the counter, and to generate latch strobe, and reset signals.

The input of F/F1 is the time base signal in the frequency measuring mode or the unknown time period in the time measuring mode.

With all circuits reset, the $\overline{Q}$ output of F/F2 holds a high level at the JK inputs of F/F1. With a pulse coming into the F/F1, Q of F/F1 changes from 0 to 1 on the negative-going edge. This 1 is applied to the first stage of the counter, allowing it to count. F/F2 does not change state since it changes only on a negative-going edge. With the next pulse to the clock input of F/F1, F/F1 changes state on the negative-going edge, changing the Q output from logical 1 to logical zero. This negative-going transition sets F/F2 and at the same time stops the counter from counting. With F/F2 set, $\overline{Q}$ of F/F2 is a 0. A 0 at the JK inputs of F/F1 inhibits change with any additional pulses coming into its clock input. The Q output of F/F2 is connected to the input of a monostable multivibrator, 1/2 SN74123. This multivibrator generates a short positive-going pulse at the Q output. The pulse width is determined by the RC combination R6C5 and is set in this application to 150 nanoseconds. The output signal is inverted and applied to the Latch Strobe inputs of the TIL306 and TIL308 devices. This pulse transfers the data from the counters into the latches to be displayed.

The $\overline{Q}$ of F/F2 is connected to the JK inputs of F/F1 and also through a resistor to transistor T1. During counting operation $\overline{Q}2$ is high, turning T1 on and preventing C4 from charging. At the end of the count cycle, the $\overline{Q}2$ is low, turning T1 off. The capacitor C4 begins charging through resistors R4 and R5. R4 is adjustable and allows a variation in the display time. R5 prevents the charging current and the current through T1 from exceeding 1 mA when R4 is turned to zero. Once the charge across C4 reaches the firing potential of the unijunction, T2, the unijunction generates a positive pulse at Base 2, which is coupled into the monostable multivibrator, SN74123. The positive pulse determined by R7C6, 150 nanoseconds wide, is inverted by an inverter, 1/6 of SN74H04, and applied to the reset input of the TIL306 devices, the four F/Fs of the first counter stage, and the two F/Fs in the control section. With F/F1 and F/F2 reset the JK inputs are reset to a high level by F/F2 and the circuit is again ready to handle the incoming signal.

The bottom part of the schematic in Figure 10 shows the counter section. The first stage is made up of two SN74S112, one SN74S11, and one TIL308. The two SN74S112 circuits and one SN74S11 circuit form a decade counter consisting of four flip-flops and one gate. Schottky TTL devices are used because of the speed requirement. If only a 70-MHz counting rate is required, this circuit could be a single SN74196 circuit. The $\overline{Q}$ output of the fourth F/F is connected to the clock input of the first TIL306. The maximum count of the TIL306 is connected to the clock input of the next TIL306. This operation is the asynchronous mode, which is acceptable for counter purposes.

The counter is controlled by the two inputs to the first F/F of the first decade. The clock input is the unknown frequency in the frequency mode, or the known time pulses from the time base in the time-measuring mode. The JK inputs are connected to the Q output of the control F/F. This signal gates the counter. As already explained, a high level to the JK inputs allows the F/F to change state on a negative edge of a pulse applied to the clock input. With the JK inputs low, the clock input does not affect the F/F.

To complete the operation of the counter, the Latch Strobe and the Reset are applied to the circuit as shown. S3 allows choosing between suppression or displaying of zeroes to the left of the most significant digit. With the switch closed, a ground is applied to the ripple blanking input of the most significant digit. If this digit is a zero, the display is blanked and the ripple blanking output goes zero. This output is connected to the next digit and the process repeated until all leading zeroes are suppressed. If switch S3 is opened the high-order zeroes are displayed. All that is necessary for operation of the counter now is to provide a power supply and a signal to be counted.

Hermetic Displays

HERMETIC DISPLAYS
QUICK REFERENCE GUIDE

DEVICE	TYPE OF CHARACTER(S)	CHARACTER HEIGHT (INCHES)	COLOR OF DISPLAY	PACKAGE	REMARKS
4N41	7-segment	0.270	Red	14-lead hermetically sealed dual-in-line	Formerly TIL501. Electrically and mechanically interchangeable with TIL302.
TIL504	5 X 7 alphanumeric	0.300	Red	14-lead hermetically sealed dual-in-line	Electrically interchangeable with TIL305.
TIL506	7-segment	0.300	Red	8-lead hermetically sealed	Internal TTL MSI chip with decoder and driver. Left Decimal.
TIL507	5 X 7 alphanumeric	0.300	Red	16-lead hermetically sealed dual-in-line	Integral D-type flip-flop column drivers and series limiting resistors. Left decimal.
TIL560	5 X 7 alphanumeric	0.500	Red	28-lead hermetically sealed	Three 5 X 7 alphanumeric characters. Logic includes two SN54164 8-bit shift-register chips. Pins fit Navy WS6157/1 Series sockets.

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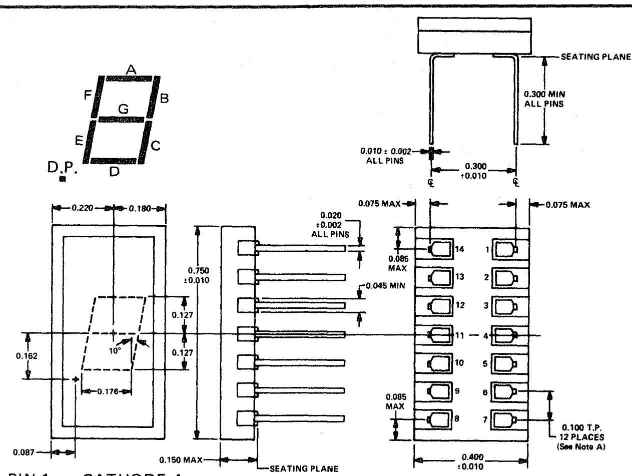
HERMETICALLY SEALED SOLID-STATE VISIBLE DISPLAY (FORMERLY TIL501)

- **Electrically and Mechanically Interchangeable with TIL302**
- **0.270-Inch-High Character**
- **High Luminous Intensity**
- **Low Power Requirements**
- **Withstands Severe Environmental Conditions**
- **Left-Hand Decimal**
- **Wide Viewing Angle**
- **Compatible with Most TTL and DTL Circuits**
- **Each Unit Checked for Uniformity of Elements**

*mechanical data

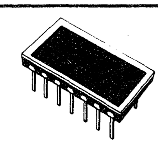
The display is mounted on a ceramic header, which is then hermetically sealed to a glass cover. Multiple displays may be mounted on 0.450-inch centers.



PIN 1 – CATHODE A
PIN 2 – CATHODE F
PIN 3 – ANODE E, F, G, & DECIMAL
PIN 4 – NC
PIN 5 – NC
PIN 6 – CATHODE DECIMAL
PIN 7 – CATHODE E
PIN 8 – CATHODE D
PIN 9 – ANODE C, D
PIN 10 – CATHODE C
PIN 11 – CATHODE G
PIN 12 – NC
PIN 13 – CATHODE B
PIN 14 – ANODE A, B

NC – No internal connection

NOTES:
A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within 0.010 of its true longitudinal position relative to pins 4 and 11.
B. Lead dimensions are not controlled above the seating plane.
C. Centerlines of character segments and decimal points are shown as dashed lines. Associated dimensions are nominal.
D. All dimensions are in inches unless otherwise specified.



*JEDEC registered data. This data sheet contains all applicable registered data in effect at the time of publication.

9

*absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature:
- Each Segment . . . . . 6 V
- Decimal Point . . . . . 3 V

Peak Forward Current at (or below) 70°C Free-Air Temperature, (See Note 1)
- Each Segment or Decimal Point . . . . . 200 mA

Average Forward Current at (or below) 70°C Free-Air Temperature (See Notes 2 and 3):
- Each Segment or Decimal Point . . . . . 30 mA
- Total . . . . . 240 mA

Operating Free-Air Temperature Range . . . . . −55°C to 100°C
Storage Temperature Range . . . . . −65°C to 125°C
Lead Temperature 1/16 Inch Below the Seating Plane for 10 Seconds . . . . . 260°C

NOTES: 1. Derate linearly to 100°C free-air temperature at the rate of 6.67 mA/°C.
2. These average values apply for any 10-ms period.
3. Derate linearly to 100°C free-air temperature at the rates of 1 mA/°C for each segment or decimal point and 8 mA/°C for the total device.

*operating characteristics of each segment at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V	Luminous Intensity (See Note 4)	I_F = 20 mA	200	700		µcd
λ_p	Wavelength at Peak Emission		640	660	680	nm
$\Delta\lambda$	Spectral Bandwidth			20		nm
V_F	Static Forward Voltage		3	3.4	3.8	V
α_{VF}	Average Temperature Coefficient of Static Forward Voltage	I_F = 20 mA, T_A = 0°C to 100°C		−2.7		mV/°C
I_R	Static Reverse Current	V_R = 6 V			100	µA
C	Anode-to-Cathode Capacitance	V_R = 0, f = 1 MHz		85		pF

*operating characteristics of decimal point at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V	Luminous Intensity (See Note 4)	I_F = 20 mA	100	350		µcd
λ_p	Wavelength at Peak Emission		640	660	680	nm
$\Delta\lambda$	Spectral Bandwidth			20		nm
V_F	Static Forward Voltage		1.5	1.65	2	V
α_{VF}	Average Temperature Coefficient of Static Forward Voltage	I_F = 20 mA, T_A = 0°C to 100°C		−1.4		mV/°C
I_R	Static Reverse Current	V_R = 3 V			100	µA
C	Anode-to-Cathode Capacitance	V_R = 0, f = 1 MHz		120		pF

NOTE 4: Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

*JEDEC registered data

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TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

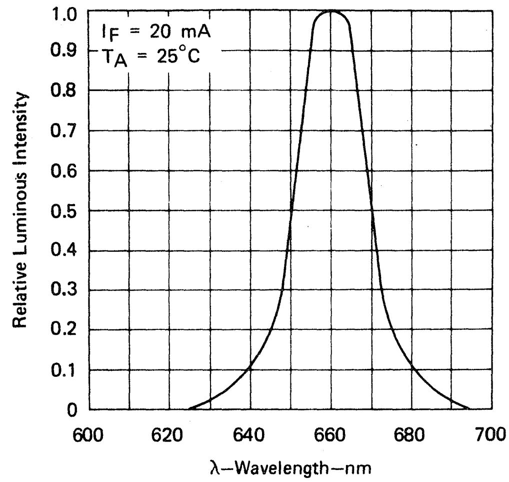


FIGURE 1

RELATIVE LUMINOUS INTENSITY
vs
FREE-AIR TEMPERATURE

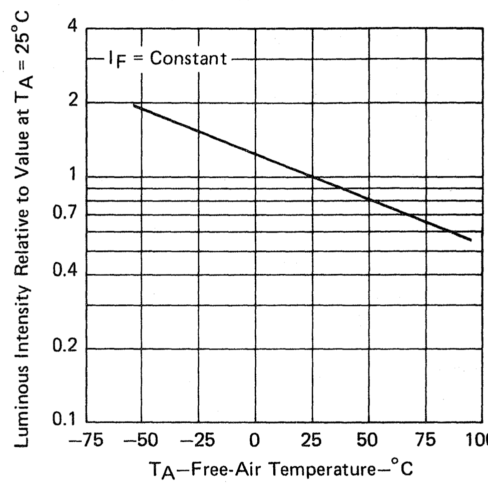


FIGURE 2

RELATIVE LUMINOUS INTENSITY
vs
FORWARD CURRENT

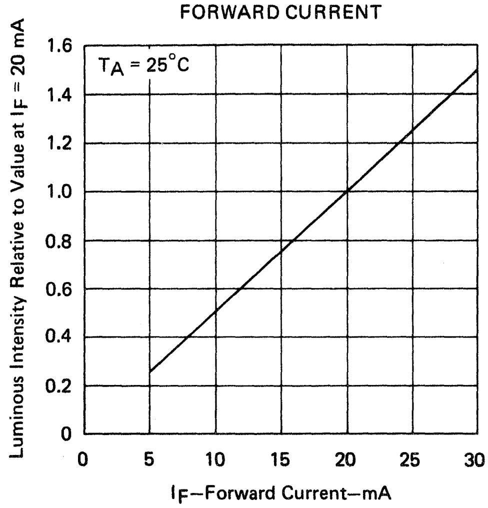


FIGURE 3

FORWARD CONDUCTION CHARACTERISTICS

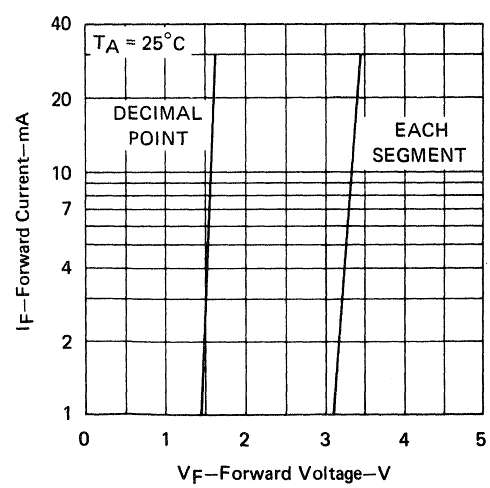
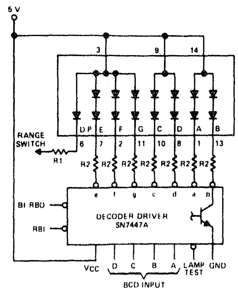
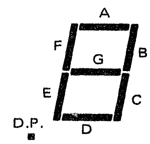


FIGURE 4

9

TYPICAL APPLICATION DATA





NOTES: A. R1 and R2 are selected for desired brightness.
B. SN74L47 may be used in place of SN7447A in applications where segment forward current will not exceed 20 mA, or SN74LS47 may be used for current up to 24 mA. An alternate font is available in the SN74247 and SN74LS247. For use below 0°C and/or above 70°C, substitute parts from the 54 Family.

FUNCTION TABLE
SN7447A, SN74L47, SN74LS47

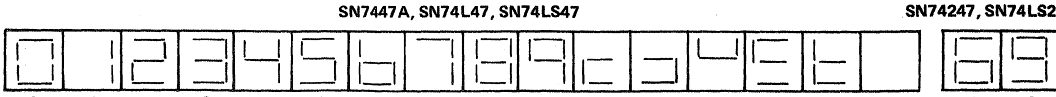
DECIMAL OR FUNCTION	INPUTS						BI/RBO†	SEGMENTS							NOTE
	LT	RBI	D	C	B	A		a	b	c	d	e	f	g	
0	H	H	L	L	L	L	H	ON	ON	ON	ON	ON	ON	OFF	1
1	H	X	L	L	L	H	H	OFF	ON	ON	OFF	OFF	OFF	OFF	1
2	H	X	L	L	H	L	H	ON	ON	OFF	ON	ON	OFF	ON	1
3	H	X	L	L	H	H	H	ON	ON	ON	ON	OFF	OFF	ON	1
4	H	X	L	H	L	L	H	OFF	ON	ON	OFF	OFF	ON	ON	1
5	H	X	L	H	L	H	H	ON	OFF	ON	ON	OFF	ON	ON	1
6	H	X	L	H	H	L	H	OFF‡	OFF	ON	ON	ON	ON	ON	1
7	H	X	L	H	H	H	H	ON	ON	ON	OFF	OFF	OFF	OFF	1
8	H	X	H	L	L	L	H	ON	ON	ON	ON	ON	ON	ON	1
9	H	X	H	L	L	H	H	ON	ON	ON	OFF‡	OFF	ON	ON	1
10	H	X	H	L	H	L	H	OFF	OFF	OFF	ON	ON	OFF	ON	1
11	H	X	H	L	H	H	H	OFF	OFF	ON	ON	OFF	OFF	ON	1
12	H	X	H	H	L	L	H	OFF	ON	OFF	OFF	OFF	ON	ON	1
13	H	X	H	H	L	H	H	ON	OFF	OFF	ON	OFF	ON	ON	1
14	H	X	H	H	H	L	H	OFF	OFF	OFF	ON	ON	ON	ON	1
15	H	X	H	H	H	H	H	OFF	OFF	OFF	OFF	OFF	OFF	OFF	1
BI	X	X	X	X	X	X	L	OFF	OFF	OFF	OFF	OFF	OFF	OFF	2
RBI	H	L	L	L	L	L	L	OFF	OFF	OFF	OFF	OFF	OFF	OFF	3
LT	L	X	X	X	X	X	H	ON	ON	ON	ON	ON	ON	ON	4

H = high level (logic 1 in positive logic), L = low level (logic 0 in positive logic), X = irrelevant.

†BI/RBO is wire-AND logic serving as blanking input (BI) and/or ripple-blanking output (RBO).
‡These segments would be on if the SN74247 or SN74LS247 were used.

NOTES: 1. The blanking input (BI) must be open or held at a high logic level when output functions 0 through 15 are desired. The ripple-blanking input (RBI) must be open or high if blanking of a decimal zero is not desired.
2. When a low logic level is applied directly to the blanking input (BI), all segment outputs are off regardless of any other input.
3. When the ripple-blanking input (RBI) and inputs A, B, C, and D are at a low logic level with the lamp test input high, all segment outputs are off and the ripple-blanking output (RBO) of the decoder goes to a low level (response condition).
4. When the blanking input/ripple blanking output (BI/RBO) is open or held high and a low is applied to the lamp-test input, all segments are illuminated.

SN7447A, SN74L47, SN74LS47 **ALTERNATE FONT SN74247, SN74LS247**



0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 6 9

NUMERICAL DESIGNATIONS—RESULTANT DISPLAYS
RECOMMENDED DECODE/DRIVE WITH BCD INPUTS

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

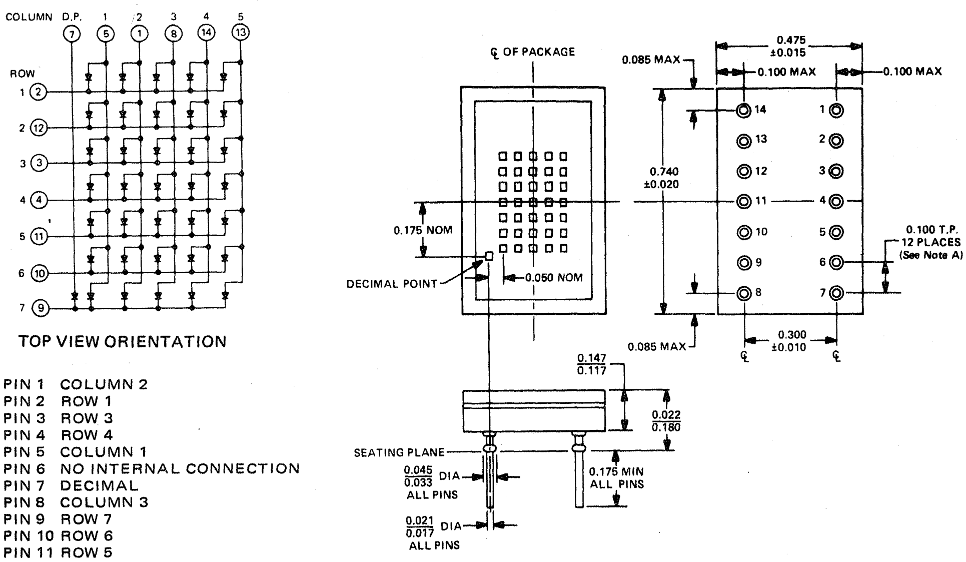
BULLETIN NO. DL-S 7612210, NOVEMBER 1974—REVISED MARCH 1976

HERMETICALLY SEALED SOLID-STATE VISIBLE DISPLAY

- Electrically Interchangeable with TIL305 with Same Pin Connections
- 0.300-Inch-High Character
- High Luminous Intensity
- Low Power Requirements
- Each Unit Checked for Uniformity of Elements
- Withstands Severe Environmental Conditions
- Left-Hand Decimal
- Wide Viewing Angle
- Compatible with Most TTL and DTL Circuits

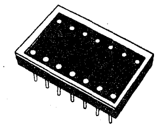
mechanical data

The display is mounted on a ceramic header which is then hermetically sealed to a glass cover. Multiple displays may be mounted on 0.5-inch centers.



PIN 1 COLUMN 2
PIN 2 ROW 1
PIN 3 ROW 3
PIN 4 ROW 4
PIN 5 COLUMN 1
PIN 6 NO INTERNAL CONNECTION
PIN 7 DECIMAL
PIN 8 COLUMN 3
PIN 9 ROW 7
PIN 10 ROW 6
PIN 11 ROW 5
PIN 12 ROW 2
PIN 13 COLUMN 5
PIN 14 COLUMN 4

NOTES: A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within 0.010 of its true longitudinal position relative to pins 4 and 11.
B. Lead dimensions are not controlled above the seating plane.
C. Vertical and horizontal spacing between centerlines of rows and columns is nominally 0.050.
D. All dimensions are in inches.



9

absolute maximum ratings

Reverse Voltage at 25°C Free-Air Temperature . . . . . 3 V
Peak Forward Current at (or below) 70°C free-air temperature, Each Diode (See Note 1) . . . . . 100 mA
Average Forward Current at (or below) 70°C Free-Air Temperature (See Notes 2 and 3):
- Each Diode . . . . . 20 mA
- Total . . . . . 400 mA

Operating Free-Air Temperature Range . . . . . −55°C to 100°C
Storage Temperature Range . . . . . −65°C to 125°C

operating characteristics of each diode at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V	Luminous Intensity (See Note 4)	I_F = 10 mA	80	150		μcd
λ_p	Wavelength at Peak Emission		640	660	680	nm
$\Delta\lambda$	Spectral Bandwidth			20		nm
V_F	Static Forward Voltage		1.5	1.65	2	V
α_{VF}	Average Temperature Coefficient of Static Forward Voltage	I_F = 10 mA, T_A = 0°C to 100°C		−1.4		mV/°C
I_R	Static Reverse Current	V_R = 3 V			100	μA
C	Anode-to-Cathode Capacitance	V_R = 0, f = 1 MHz		80		pF

NOTES: 1. Derate to 100°C free-air temperature at the rate of 3.33 mA/°C.
2. This value applies for any 250-μs period.
3. Derate linearly to 100°C free-air temperature at the rates of 0.67 mA/°C for each diode and 13.3 mA/°C for the total device.
4. Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission and Illumination) eye-response curve.

TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

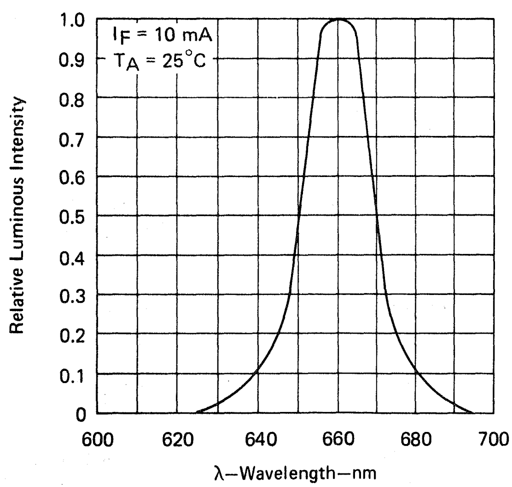


FIGURE 1

RELATIVE LUMINOUS INTENSITY
vs
FREE-AIR TEMPERATURE

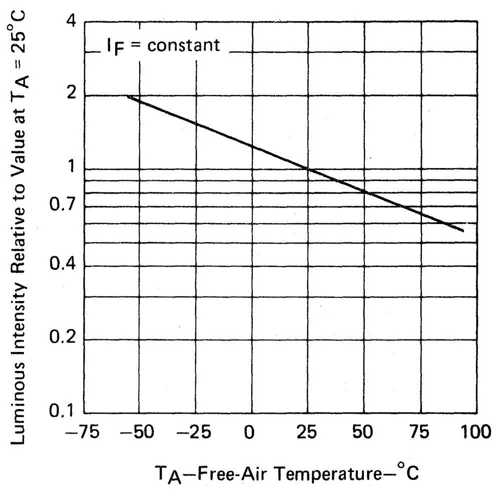


FIGURE 2

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TYPICAL CHARACTERISTICS

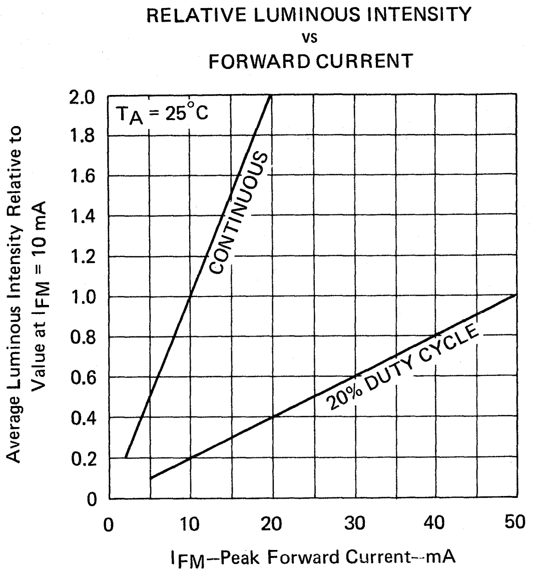

FIGURE 3

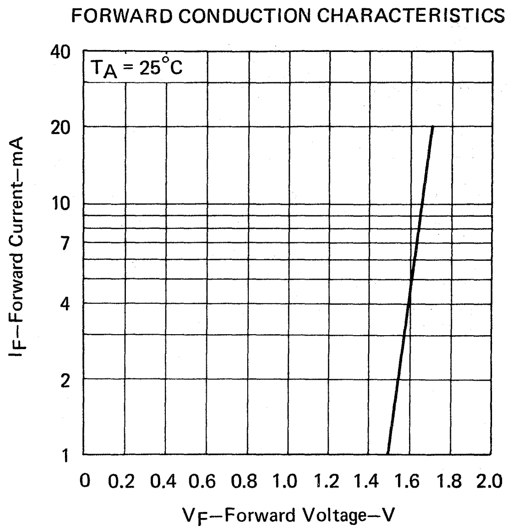

FIGURE 4

TYPICAL APPLICATION DATA

The TIL504 is used as a single character display in the application illustrated in Figure 5. The character displayed is a function of the logic input lines 1 through 7 and the blanking input. A low-logic-level voltage applied to the blanking input will inhibit the display.

The five columns of the TIL504 are scanned with a 20% duty cycle. The sequencing is controlled by the unijunction transistor oscillator, SN7496 shift register, and one of the SN7416 hex inverter/buffer drivers that are used to invert and feed the outputs back to the serial input to form a ring counter.

The outputs of the ring counter are used to drive the column drivers (A5T2907's) and the column select inputs of the read-only memory after being inverted through another SN7416.

The logic inputs 1 through 7 are inverted with another SN7416 to make the inputs compatible with positive logic and Series 54/74 levels.

If the coding at the inputs 1 through 7 is USASCII, a TMS4103JC or TMS4103NC read-only memory may be used to display the alpha-numeric characters per Figure 6. If the coding is EBCDIC, then a TMS4179JC or TMS4179NC will display the alpha-numeric characters per Figure 7. The TMS4103 and TMS4179 are pin-for-pin replacements in this circuit. Other codes may be used with a custom TMS4100 read-only memory.

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TYPICAL APPLICATION DATA

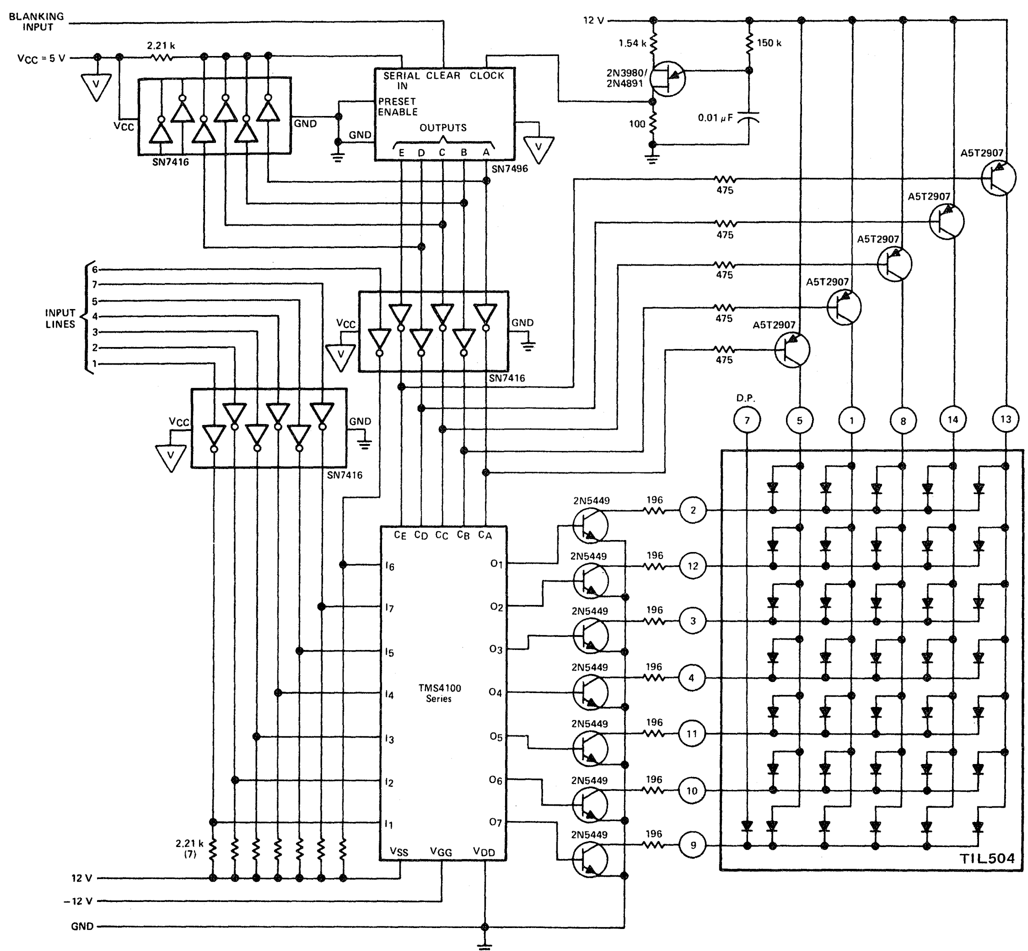


FIGURE 5

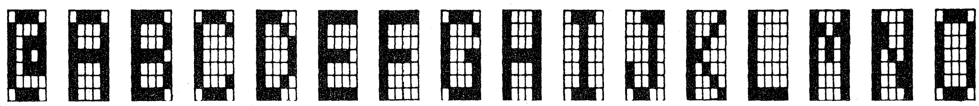
Resistor values are in ohms.

▽ . . . V_{CC} bus.

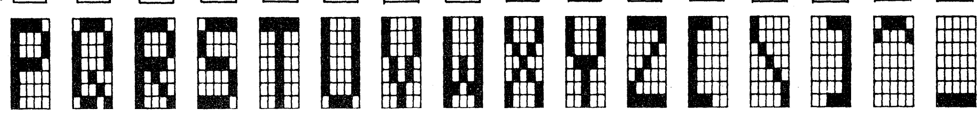
TYPICAL APPLICATION DATA

RESULTANT DISPLAYS USING TMS4103JC OR TMS4103NC WITH USASCII CODED INPUTS

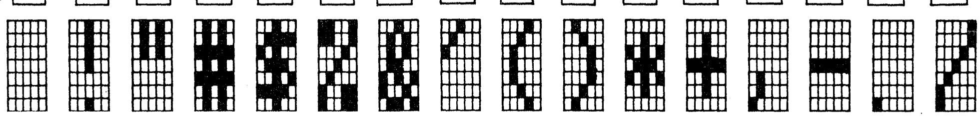
1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



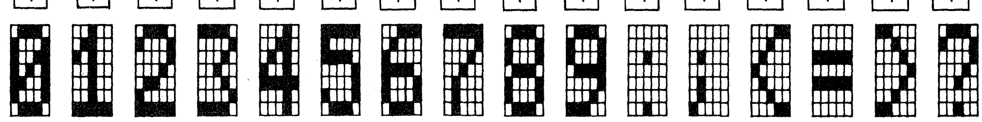
1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



positive logic: 1 = H = 2 V to 5.5 V
0 = L = 0 V to 0.8 V

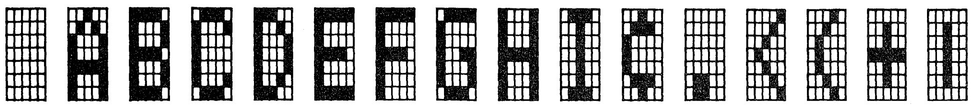
FIGURE 6

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

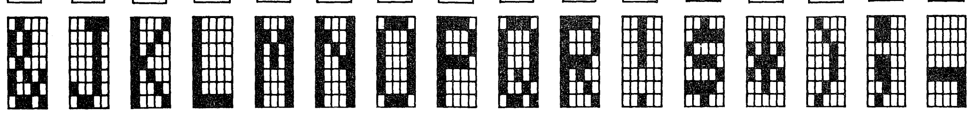
TYPICAL APPLICATION DATA

RESULTANT DISPLAYS USING TMS4179JC OR TMS4179NC WITH EBCDIC CODED INPUTS

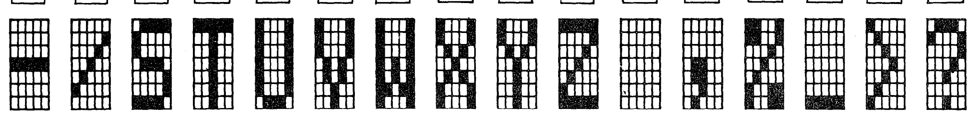
1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



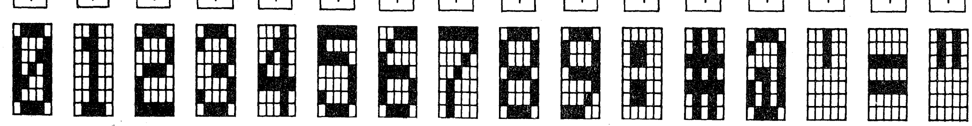
1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



positive logic: 1 = H = 2 V to 5.5 V
0 = L = 0 V to 0.8 V

FIGURE 7

TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

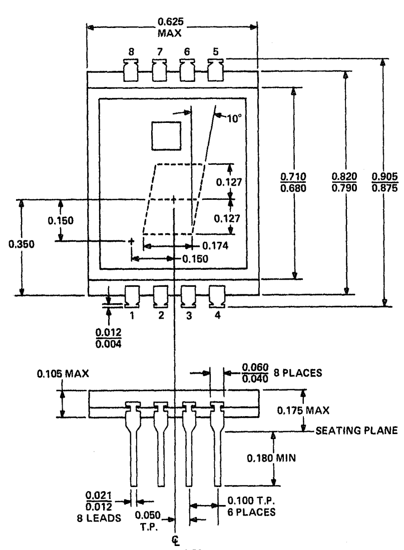
BULLETIN NO. DL-S 7412225, NOVEMBER 1974

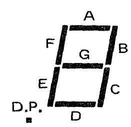
HERMETICALLY SEALED SOLID-STATE SEVEN-SEGMENT VISIBLE DISPLAY WITH TTL DECODER/DRIVER

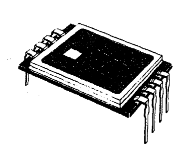
- **Withstands Military Environmental Conditions**
- **0.300-Inch-High Character**
- **Internal TTL MSI Chip with Decoder and Driver**
- **BCD Four-Line Input**
- **Wide Viewing Angle**
- **High Luminous Intensity**
- **Left-Hand Decimal**
- **Constant-Current Drive for Light-Emitting Diodes**
- **Compatible with Most TTL and DTL Circuits**

mechanical data

The display and TTL logic chip are mounted on a ceramic header which is then hermetically sealed to a glass lid. Multiple displays may be mounted on 0.625-inch centers.







PIN 1 DATA INPUT $\overline{A}$
(BINARY WEIGHT 1)
PIN 2 DECIMAL POINT INPUT
PIN 3 LED SUPPLY VOLTAGE, V_{LED}
PIN 4 DATA INPUT $\overline{D}$
(BINARY WEIGHT 8)
PIN 5 DATA INPUT $\overline{C}$
(BINARY WEIGHT 4)
PIN 6 GROUND
PIN 7 LOGIC SUPPLY VOLTAGE, V_{CC}
PIN 8 DATA INPUT $\overline{B}$
(BINARY WEIGHT 2)

NOTES:
A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located within 0.010 of its true longitudinal position relative to the package centerline.
B. Centerlines of character segments and decimal points are shown as dashed lines. Associated dimensions are nominal.
C. All dimensions are in inches unless otherwise specified.

9

description

The TIL506 contains a seven-segment numeric display with left-hand decimal and a TTL MSI BCD-to-seven-segment decoder and driver. It accepts four-line binary-coded-decimal (BCD) input in negative logic and displays the decimal number in a seven-segment format. Invalid inputs are automatically blanked (see function table). A high-logic-level voltage (⩾ 2 V) at the decimal point input turns on the decimal independently of the BCD inputs. The decimal point, as well as each segment, is driven by a constant current from the logic chip. Varying the LED supply voltage will not significantly affect the brightness of the display. The brightness may be controlled by pulse width modulation of the BCD inputs alternating between a valid code and an invalid code (e.g. all inputs low).

FUNCTION TABLE

FUNCTION	DATA INPUTS $\overline{D}$	$\overline{C}$	$\overline{B}$	$\overline{A}$	DP	DISPLAY
0	H	H	H	H	L	0
1	H	H	H	L	H	.1
2	H	H	L	H	L	2
3	H	H	L	L	H	.3
4	H	L	H	H	L	4
5	H	L	H	L	H	.5
6	H	L	L	H	L	6
7	H	L	L	L	H	.7
8	L	H	H	H	L	8
9	L	H	H	L	H	.9
BLANK	L	H	L	H	L	
BLANK	L	H	L	L	H	.
BLANK	L	L	H	H	L	
BLANK	L	L	H	L	H	.
BLANK	L	L	L	H	L	
BLANK	L	L	L	L	H	.

H = high logic level, L = low logic level
DP input has arbitrarily been shown activated (high) on every other line of the table.

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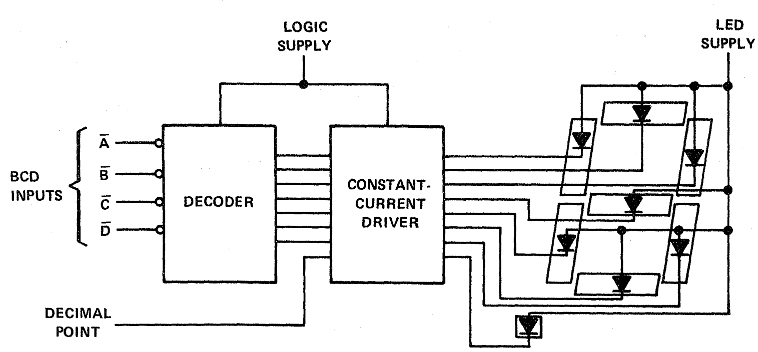
functional block diagram



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Logic Supply Voltage, V_{CC} (See Note 1)	7 V
LED Supply Voltage, V_{LED}, at (or below) 70°C Free-Air Temperature (See Note 2)	5.5 V
Data Input Voltage	5.5 V
Operating Free-Air Temperature Range	−55°C to 100°C
Storage Temperature Range	−65°C to 125°C

NOTES: 1. Voltage values are with respect to the ground terminal.
2. For operation above 70°C free-air temperature, refer to LED Supply Voltage Derating Curve, Figure 1.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Logic Supply Voltage, V_{CC}	4.5	5	5.5	V
LED Supply Voltage, V_{LED} (See Figure 1)	4 V	4.6	5 V	V
Operating Free-Air Temperature, T_A	−55		100	°C

LED SUPPLY VOLTAGE DERATING CURVE

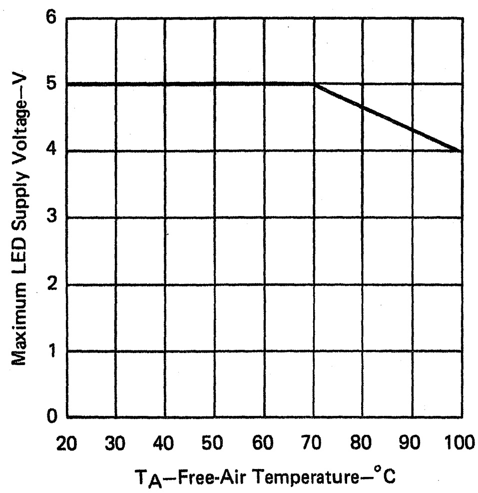


FIGURE 1

operating characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_v	Luminous Intensity (See Note 3)	Each Segment	V_{CC} = 5 V, V_{LED} = 4.6 V, See Note 4	700			µcd
		Decimal Point		40			
λ_p	Wavelength at Peak Emission			640	655	670	nm
$\Delta\lambda$	Spectral Bandwidth				20		nm
V_{IH}	High-Level Input Voltage			2			V
V_{IL}	Low-Level Input Voltage					0.8	V
V_{IK}	Input Clamp Voltage		V_{CC} = 4.5 V, I_I = −12 mA			−1.5	V
I_I	Input Current at Maximum Input Voltage		V_{CC} = 5.5 V, V_I = 5.5 V			1	mA
I_{IH}	High-Level Input Current		V_{CC} = 5.5 V, V_I = 2.4 V			20	µA
I_{IL}	Low-Level Input Current		V_{CC} = 5.5 V, V_I = 0.4 V			−0.8	mA
I_{CC}	Logic Supply Current		V_{CC} = 5.5 V, V_{LED} = 5 V,			75	mA
I_{LED}	LED Supply Current		DP at 5 V, Other inputs at 0 V			160	mA

NOTES: 3. Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.
4. These parameters were measured with all LED segments and the decimal point on.

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TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

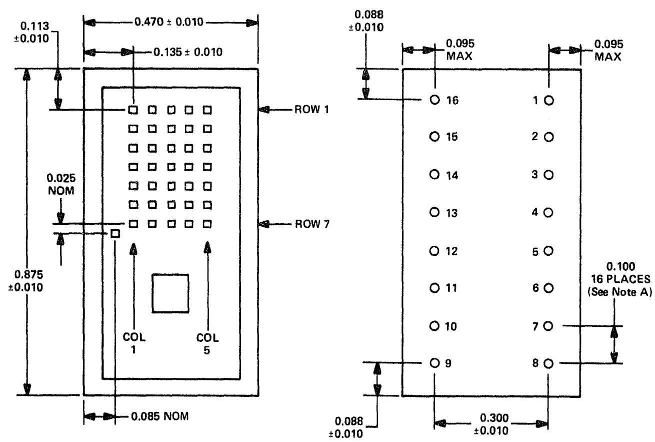
BULLETIN NO. DL-S 7612220, NOVEMBER 1974—REVISED MARCH 1976

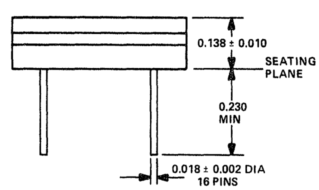
HERMETICALLY SEALED SOLID-STATE VISIBLE DISPLAY WITH INTEGRAL TTL COLUMN DRIVERS

- Withstands Military Environmental Conditions
- 0.300-Inch-High Character
- Integral D-Type Flip-Flop Column Drivers and Series Limiting Resistors
- Wide Viewing Angle
- Compatible with Most TTL and DTL Circuits
- High Luminous Intensity
- Left Decimal

mechanical data

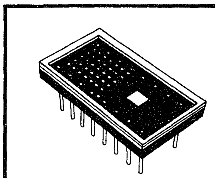
The display and TTL logic chip are mounted on a ceramic header which is then hermetically sealed to a glass window. Multiple displays may be mounted on 0.480-inch centers.





PIN 1 ROW 1
PIN 2 ROW 3
PIN 3 ROW 5
PIN 4 ROW 7 & D.P. ANODE
PIN 5 COLUMN 1
PIN 6 D.P. COLUMN
PIN 7 CLOCK
PIN 8 GROUND
PIN 9 V_{CC}
PIN 10 COLUMN 3
PIN 11 COLUMN 5
PIN 12 COLUMN 4
PIN 13 COLUMN 2
PIN 14 ROW 6
PIN 15 ROW 4
PIN 16 ROW 2

NOTES: A. The true-position pin spacing is 0.100 between centerlines. Each pin centerline is located with 0.010 of its true longitudinal position relative to pins 1 and 16.
B. Vertical and horizontal spacing between centerlines of rows and columns is nominally 0.050.
C. All dimensions are in inches.



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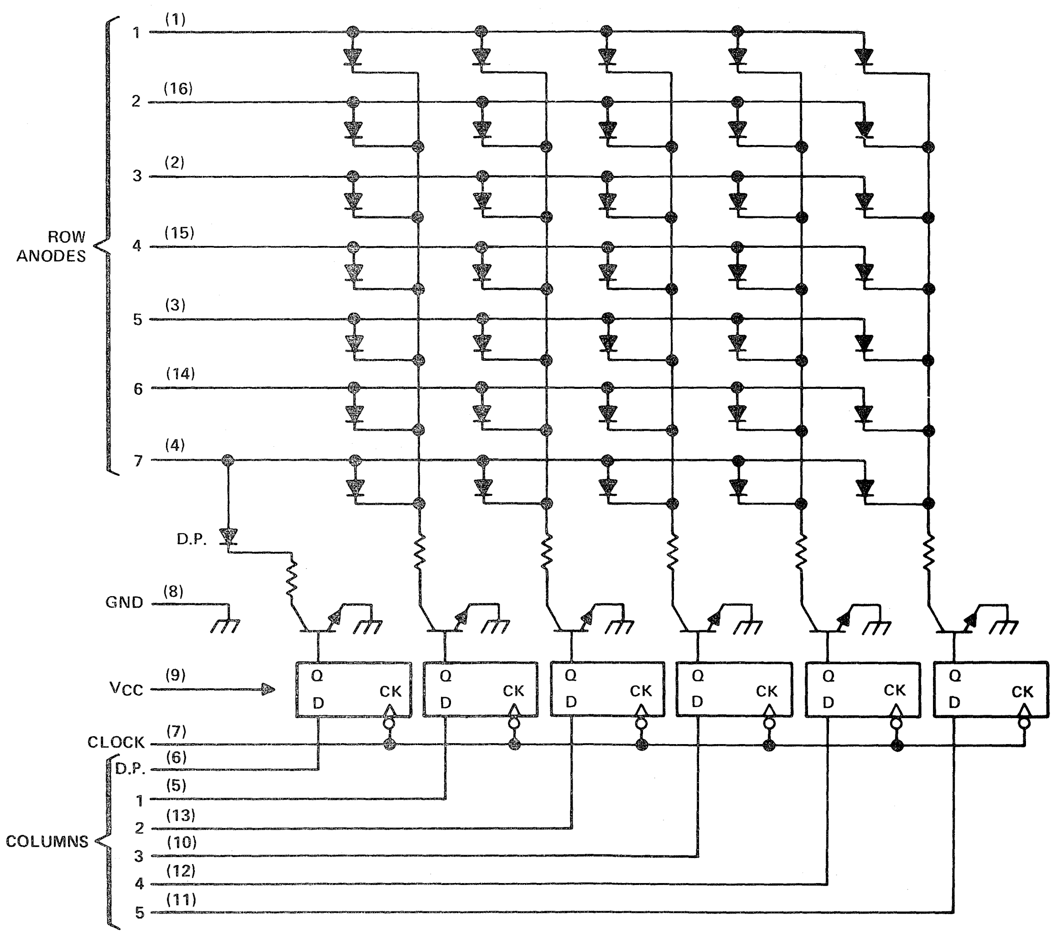
TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

description

The TIL507 is a 5 X 7 matrix of light-emitting diodes plus a decimal point. The device includes an IC logic chip similar to SN54174 containing six D-type flip-flops that can transfer data from a character generator to the five columns of the matrix and the decimal point. The chip also includes six cathode column drivers with series-limiting resistors.

The rows are strobed by sequentially applying a positive voltage to each row input. As each row is strobed the data set up at column inputs are transferred to the column drivers on the rising edge of each clock pulse. A high column input causes the LED to turn on. After the minimum hold time requirement has been satisfied, the column data inputs may change whether the clock is high or low.



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Logic Supply Voltage, V_{CC} (See Note 1)	7 V
Row Anode Voltage, V_{row}	5.5 V
Input Voltage (Column Data and Clock)	5.5 V
Operating Free-Air Temperature Range	−55°C to 100°C
Storage Temperature Range	−65°C to 125°C

NOTE 1: Voltage values are with respect to network ground terminal.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Logic Supply Voltage	4.5	5	5.5	V
High-Level Row Anode Voltage, V_{row}	3.5†	4	5	V
Clock Frequency, f_{clock}		3		MHz
Width of Clock Pulse, t_w	200			ns
Data Setup Time, t_{setup}	50			ns
Data Hold Time, t_{hold}	5			ns
Operating Free-Air Temperature, T_A	−55		100	°C

†Voltage may be reduced to 0 V to control intensity of the display.

operating characteristics at 25°C free-air temperature

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_v	Luminous Intensity (See Note 2)		V_{CC} = 5 V, I_F = 10 mA	40	110		μcd
λ_p	Wavelength at Peak Emission		V_{CC} = 5 V, V_{LED} = 4 V	640	655	670	nm
$\Delta\lambda$	Spectral Bandwidth		V_{CC} = 5 V, V_{LED} = 4 V		20		nm
V_{IH}	High-Level Input Voltage			2			V
V_{IL}	Low-Level Input Voltage					0.8	V
V_{IK}	Input Clamp Voltage		V_{CC} = 4.5 V, I_I = −12 mA			−1.5	V
I_{IH}	High-Level Input Current		V_{CC} = 5.5 V, V_I = 2.4 V			150	μA
I_{IL}	Low-Level Input Current		V_{CC} = 5.5 V, V_I = 0.4 V			−1	mA
I_{row}	Row Input Current	Row 1 thru Row 6	See Note 3		500	800	mA
I_{row}	Row Input Current	Row 7	See Note 3		600	1000	mA
I_{CC}	Logic Supply Current		See Note 3		45	65	mA

NOTES: 2. Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.

3. Maximum values of row input current and logic supply current are stated for V_{CC} = 5.5 V, V_{row} = 5 V. Typical values are stated for V_{CC} = 5 V, V_{row} = 4 V. All column data inputs are high.

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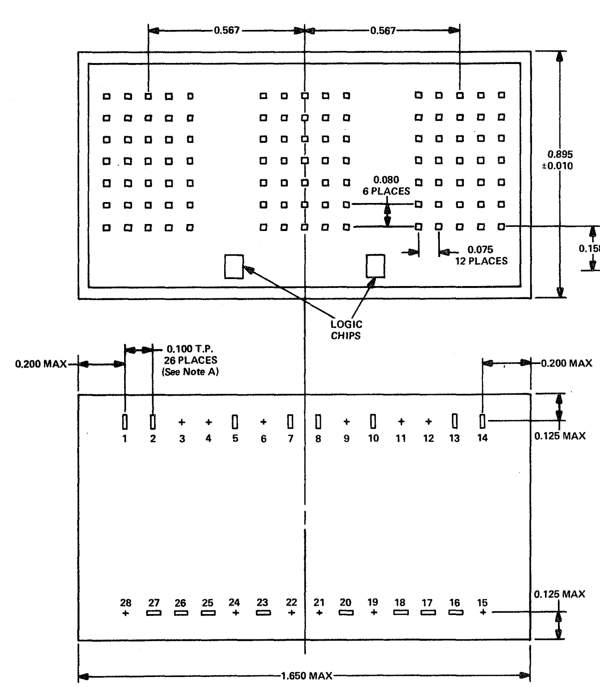
TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

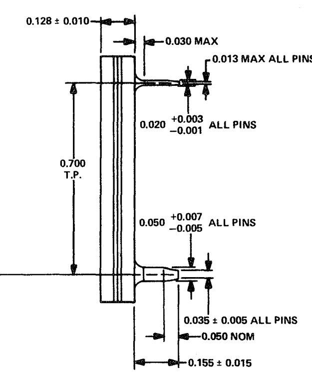
SOLID-STATE THREE-CHARACTER 5 X 7 ALPHANUMERIC DISPLAY IN A HERMETIC PACKAGE

- Meets Hermeticity Requirement of MIL-STD-883
- Large Characters . . . 0.5-Inch High
- Displays Stackable on 1.7-Inch Centers
- Wide Viewing Angle
- Pins Fit Navy WS6157/1 Series Sockets
- TTL Shift Register with Serial Input Minimizes Input Pins
- Shift Register Serial Data Output to Serially Address Several Packages
- TTL Compatible
- Integrated Resistors and a Capacitor

mechanical data

The displays and logic chips are mounted on a substrate which is then hermetically sealed to a glass lid. All external metal parts are gold plated. The pins are designed for reliable interconnection with the Navy WS6157/1 Series sockets, which can be purchased from Masterite Industries, Torrence, California (028-Series). The pins are keyed to prevent inserting the display into the socket upside-down. Character-to-character spacing is maintained when multiple displays are mounted on 1.7 inch centers.



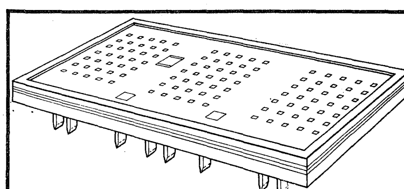


PIN ASSIGNMENTS

1 SERIAL DATA OUTPUT	15 OMITTED
2 V_{CC}	16 ROW 7 ANODES
3 OMITTED	17 ROW 5 ANODES
4 OMITTED	18 ROW 4 ANODES
5 GROUND	19 OMITTED
6 OMITTED	20 ROW 3 ANODES
7 CLOCK	21 OMITTED
8 INTERNAL CONNECTION†	22 OMITTED
9 OMITTED	23 ROW 1 ANODES
10 GROUND	24 OMITTED
11 OMITTED	25 ROW 2 ANODES
12 OMITTED	26 NO CONNECTION
13 DATA INPUT	27 ROW 6 ANODES
14 INTERNAL CONNECTION†	28 OMITTED

†Make no external connection

NOTES: A. The true-position pin spacing is 0.100 between pin centerlines and 0.700 between row centerlines. Each pin centerline is located within 0.015 radius of true position.
B. Dimensions associated with position of LED's are between centerlines and are nominal.
C. All dimensions are in inches.



9

description

This alphanumeric display contains three 35-bit (5 X 7) characters. It is suitable for exhibiting all characters in the USASCII code using a standard MOS character generator. Two SN54164 8-bit shift-register chips are integrated to allow a single pin for entering column data. Only the first 15 bits are used. In typical operation, data for a given row are entered serially into the register and shifted from right to left. Hence, the bit for the left-hand column is entered first. Then the row-anode terminal is pulsed high and each LED corresponding to a low column data bit turns on. Following this, column data for the next row are entered.

A serial data output pin is available for connecting N display modules serially so that 3N characters can be operated off one data line. The maximum value for N depends on the row refresh rate and the clock frequency.

An internal resistor in series with each shift register output used controls the light-emitting diode (LED) current. The resistor value is matched to the LED chips to control light intensity, but, in no case is the LED peak current greater than 12 milliamperes. An 0.02-μF capacitor is included in each display module to filter out transients caused by the power supply and the TTL circuits.

A description of the functions of the inputs and the output of the TIL560 follows:

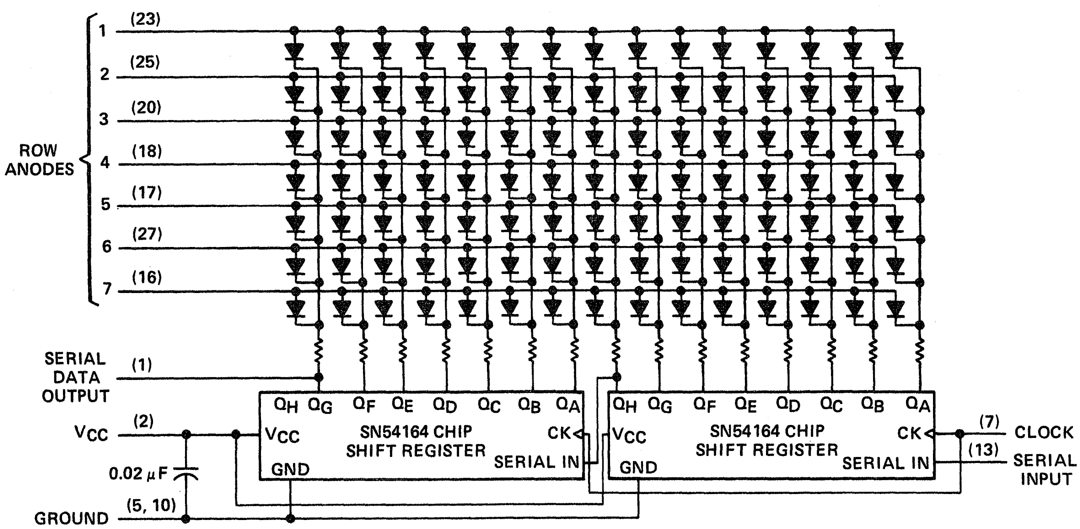
FUNCTION	PIN NO.	DESCRIPTION
ROW ANODES (1, 2, 3, 4, 5, 6, 7)	23, 25, 20, 18, 17, 27, 16	When high, these inputs supply current to the LED chips in that row for which the column input data bit is low.
DATA INPUT	13	This input is used to enter column data, left-hand column first, into the display. A low level corresponds to turning the LED on while a high level blocks the row input current from the LED.
CLOCK INPUT	7	The column data entered at the data input is shifted one bit to the left on each low-to-high transition of the clock input.
DATA OUTPUT	1	To operate more than one display module serially, this output is connected to the data input of the module to the left. Otherwise, this output should be left open.
LOGIC SUPPLY (V_{CC})	2	This is the positive terminal for the power supply to the shift registers. The internal capacitor is connected between V_{CC} and ground.
GROUND	5, 10	These are the negative terminals for V_{CC} and the row, data, and clock inputs. They should be externally connected together.

9

reliability testing

Every display is subjected to the following tests according to MIL-STD-883: pre-cap visual inspection, Method 2010, Condition B; temperature cycling, Method 1010, Condition B except that the high temperature is 100°C; and a leak test, Method 1014, Conditions B and C.

schematic



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Logic Supply Voltage, V_{CC} (See Note 1)	7 V
Row Anode Voltage, V_{row}	5.5 V
Input Voltage (Data and Clock)	5.5 V
Operating Free-Air Temperature Range	−55°C to 85°C
Storage Temperature Range	−65°C to 125°C

NOTE 1: Voltage values are with respect to both ground pins externally connected together.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Logic Supply Voltage, V_{CC}	4.5	5	5.5	V
High-Level Row Anode Voltage, V_{row}	4	5	5.5	V
High-Level Output Current			−40	μA
Low-Level Output Current			1.6	mA
Clock Frequency, f_{clock}	0		6	MHz
Width of Clock Pulse, t_w	45			ns
Data Setup Time, t_{setup}	30			ns
Data Hold Time, t_{hold}	10			ns
Operating Free-Air Temperature, T_A	−55		85	°C

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operating characteristics over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_V	Luminous Intensity (See Note 2)		V_{CC} = 5 V, V_{row} = 5 V,	3.5	7	11	μcd
λ_p	Wavelength at Peak Emission		f_{row} = 500 Hz, Row Duty Cycle = 1/7,	630	650	670	nm
$\Delta\lambda$	Spectral Bandwidth		T_A = 25°C		30		nm
V_{IH}	High-Level Input Voltage			2			V
V_{IL}	Low-Level Input Voltage					0.8	V
V_{IK}	Input Clamp Voltage		V_{CC} = 4.5 V, I_I = −12 mA			−1.5	V
V_{OH}	High-Level Output Voltage		V_{CC} = 4.5 V, I_{OH} = −40 μA	2.4			V
V_{OL}	Low-Level Output Voltage		V_{CC} = 4.5 V, I_{OL} = 1.6 mA, One row input at 4.5 V			0.4	V
I_I	Input Current at Maximum Input Voltage		V_{CC} = 5.5 V, V_I = 5.5 V			1	mA
I_{IH}	High-Level Input Current	Data	V_{CC} = 5.5 V, V_I = 2.4 V			40	μA
		Clock				80	
I_{IL}	Low-Level Input Current	Data	V_{CC} = 5.5 V, V_I = 0.4 V			−1.6	mA
		Clock				−3.2	
I_{OS}	Short-Circuit Output Current		V_{CC} = 5.5 V	−9		−27.5	mA
I_{row}	Row Input Current		See Note 3		126	170	mA
I_{CC}	Logic Supply Current		See Note 3		74	108	mA

NOTES: 2. Luminous intensity is measured with a light sensor and filter combination that approximates the CIE (International Commission on Illumination) eye-response curve.
3. Maximum values of row input current and logic supply current are stated for V_{CC} = 5.5 V, V_{row} = 5.5 V. Typical values are stated for V_{CC} = 5 V, V_{row} = 5 V.

TYPICAL CHARACTERISTICS

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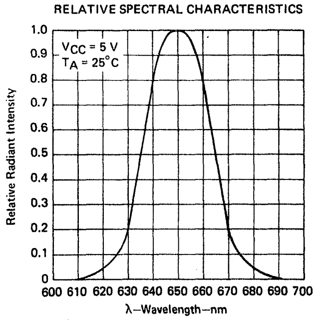

FIGURE 1

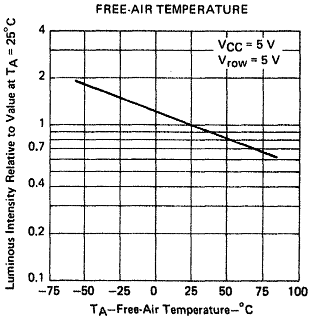

FIGURE 2

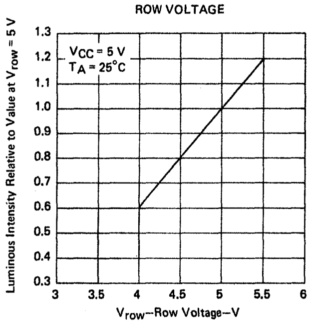

FIGURE 3

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Special Electro-optical Components

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QUICK REFERENCE GUIDE
SPECIAL ELECTRO-OPTICAL COMPONENTS

INFRARED EMITTERS

DEVICE	POWER OUTPUT MIN (mW)	@ I_F (mA)	θ_{HI} TYP	V_F MAX (V)	@ I_F (mA)	λ_p TYP (μm)	FEATURES
TIXL06	0.6	500	115°	2.3	500	0.91	0.0075-inch-dia emitting area
TIXL12	40	300	130°	2	300	0.93	0.036-inch-dia hemispherical dome emitting area
TIXL13	20	300	130°	2	300	0.93	0.036-inch-dia hemispherical dome emitting area
TIXL14	60	1000	130°	2	1000	0.93	0.072-inch-dia hemispherical dome emitting area
TIXL15	30	1000	130°	2	1000	0.93	0.072-inch-dia hemispherical dome emitting area
TIXL16A	100	2000	150°	2	2000	0.93	0.072-inch-dia dome emitting area
TIXL16B	200	2000	150°	2	2000	0.93	0.072-inch-dia dome emitting area
TIXL16C	350	3000	150°	2	3000	0.94	0.072-inch-dia dome emitting area
TIXL27	15	300	135°	2.2	300	0.94	Stud header with epoxy lens
TIXL35	0.9	50	135°	2	50	0.91	0.018-inch-dia dome emitting area
TIXL36	1	50	25°	2	50	0.91	Pill package with built-in reflector
TIXL471	0.5	50	130°	1.8	50	0.91	For connection to T-19H optical waveguide termination
TIXL474	0.07/sr	100		2	100	0.90	For coupling to single optical fibers
TIXL474A	0.12/sr	100		2	100	0.90	For coupling to single optical fibers

AVALANCHE PHOTODIODES

DEVICE	BREAKDOWN VOLTAGE MIN	MAX	@ I_R	AVALANCHE GAIN MIN	TYP	C_T TYP	R_e TYP	FEATURES	
TIXL55	155 V	185 V	100 μA	200	>600	1.2 pF	20 A/W @ 0.9 μm	Active area 0.01" dia	
TIXL56	155 V	185 V	100 μA	200	>600	1.2 pF	20 A/W @ 0.9 μm	Active area 0.01" dia	
TIXL59	155 V	185 V	100 μA	200	>600	8.5 pF	20 A/W @ 0.9 μm	Active area 0.03" dia	
TIXL69	155 V	185 V	100 μA	200	>600	30 pF	20 A/W @ 0.9 μm	Active area 0.06" dia	
TIXL83	80 V	120 V	100 μA	200	>600	4 pF	25 A/W @ 0.63 μm	Active area 0.01" dia	
TIXL84	80 V	120 V	100 μA	200	>600	17 pF	25 A/W @ 0.63 μm	Active area 0.03" dia	
TIXL85	80 V	120 V	100 μA	200	>600	4 pF	25 A/W @ 0.63 μm	Active area 0.01" dia	Contains matched reference diode
TIXL86	80 V	120 V	100 μA	200	>600	17 pF	25 A/W @ 0.63 μm	Active area 0.03" dia	Contains matched reference diode
TIXL87	155 V	185 V	100 μA	200	>600	2.5 pF	20 A/W @ 0.9 μm	Active area 0.01" dia	Contains matched reference diode
TIXL88	155 V	185 V	100 μA	200	>600	9 pF	20 A/W @ 0.9 μm	Active area 0.03" dia	Contains matched reference diode
TIXL89	155 V	185 V	100 μA	200	>600	30 pF	20 A/W @ 0.9 μm	Active area 0.06" dia	Contains matched reference diode
TIXL451	155 V	185 V	100 μA	200	>600	8.5 pF	20 A/W @ 0.9 μm	For connection to T-19H optical waveguide termination	

AVALANCHE PHOTODETECTOR MODULES

DEVICE	RADIANT RESPONSIVITY MIN (mV/nW)	TYP (mV/nW)	@ λ (μm)	AVALANCHE GAIN TYP	B_m MIN (MHZ)	P_n MAX (pW/$\sqrt{Hz}$)	FEATURES
TIXL90	0.4	0.61	0.63	200	15	0.2	Optimized for high-speed detection of visible light
TIXL91	0.2	0.3	0.63	100	15	0.4	Optimized for high-speed detection of visible light
TIXL92	0.2	0.3	0.63	200	40	0.25	Optimized for high-speed detection of visible light
TIXL93	0.1	0.15	0.63	100	40	0.5	Optimized for high-speed detection of visible light
TIXL94	0.3	0.47	0.9	200	15	0.25	Optimized for high-speed detection of near-infrared radiation
TIXL95	0.16	0.24	0.9	100	15	0.5	Optimized for high-speed detection of near-infrared radiation
TIXL96	0.15	0.23	0.9	200	40	0.3	Optimized for high-speed detection of near-infrared radiation
TIXL97	0.07	0.11	0.9	100	40	0.65	Optimized for high-speed detection of near-infrared radiation
TIXL452	0.075	0.15	0.9	125	40	0.5	For connection to T-19H optical waveguide termination

OPTICAL WAVEGUIDE TRANSMITTER MODULE

DEVICE	POWER OUTPUT MIN	@ I_F	θ_{HI} TYP	λ_p TYP	t_r MAX	FEATURES
TIXL472	0.5 mW	50 mA	130°	0.91 μm	20 ns	For connection to T-19H optical waveguide termination

OTHER PHOTODIODES

DEVICE	BREAKDOWN VOLTAGE MIN	RESPONSIBILITY TYP	C_T TYP	RISE TIME TYP	FEATURES
TIXL80	200 V @ I_R = 100 μA	0.6 A/W @ 0.9 μm	5 pF	15 ns	Large area – active area 0.10" dia
TIXL82	250 V @ I_R = 100 μA	0.68 A/W @ 0.9 μm	15 pF	15 ns	Large area quadrant geometry – active area 0.65" dia
TIXL98	50 V @ I_R = 100 μA	0.5 A/W @ 0.9 μm	1.5 pF	45 ns	High-resistivity – active area 0.04" dia

AMPLIFIERS

DEVICE	EQUIVALENT INPUT NOISE CURRENT	z_i TYP	z_o TYP	z_f TYP	BANDWIDTH TYP	FEATURES
TIXL150	7.5 pA/$\sqrt{Hz}$ TYP	35 Ω	0.5 Ω	1 kΩ	100 MHz	Low-noise, high-speed amplifiers designed for use with photodiodes
TIXL151	4.5 pA/$\sqrt{Hz}$ TYP	100 Ω	2 Ω	4 kΩ	50 MHz	Low-noise, high-speed amplifiers designed for use with photodiodes
TIXL152	3 pA/$\sqrt{Hz}$ TYP	300 Ω	4 Ω	12 kΩ	20 MHz	Low-noise, high-speed amplifiers designed for use with photodiodes

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TEXAS INSTRUMENTS
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SPECIAL ELECTRO-OPTICAL COMPONENTS

This section includes a variety of precision-made, high-performance optoelectronic products especially designed for:

- Optical ranging instruments
- Guidance systems
- Optical communications
- IR illumination

Included are high-power gallium arsenide infrared emitters, signal detectors and amplifiers, and a special family of devices optimized for use in fiber-optic communication and data transmission.

high-power gallium arsenide infrared emitters

The GaAs IRED's in this section may be categorized into two basic types: diffused-junction or grown-junction. A summary of their characteristics depicts the differences between the two:

	DIFFUSED-JUNCTION	GROWN-JUNCTION
DEVICE DESIGNATIONS	TIXL06, TIXL35, TIXL36	TIXL12 thru TIXL16, TIXL27
POWER RANGE	0.6 to 4 mW	20 to 400 mW
RESPONSE TIME	10 to 30 ns	200 to 400 ns
PEAK WAVELENGTH	0.91 μm	0.94 μm
BIAS CURRENTS	50 to 500 mA	0.3 to 3 A

An article describing in greater detail the TIXL12 thru TIXL16 series of diodes can be found on page 343.

Stud headers are used for all of the devices except the TIXL36 to provide adequate heat sinking. A larger stud is used for the TIXL16 family where bias currents reach three amps. Most are hermetically sealed with a TO-5 size flat glass window can. Epoxy encapulation provides mechanical protection for the TIXL36 and also is used to shape the spatial emission pattern for the TIXL27. While the TIXL36 has a built-in reflector, the TIXL16 series can be provided with external reflectors whose solid angle is 20° or 6°.

Although these IRED's exhibit typical solid-state reliability, customer requirements for additional testing (such as environmental, mechanical, optical, or operational) or device modifications (such as heat-sink alterations, performance criteria) can be met in the Advanced IRED Product Area.

signal detectors and amplifiers

Signal detectors are that class of photodetectors designed for detection of weak optical signals at visible or near-infrared wavelengths in receiver-type applications such as rangefinders, distance meters, and optical communications. They are optimized for high quantum efficiency, low noise, and high speed.

The products included in this section are:

- Photodiodes
- Avalanche Photodiodes
- Low-Noise Amplifiers
- Photodetector Modules

In addition, Texas Instruments produces a broad range of custom detectors of various geometries including arrays and quadrants. Inquiries on custom detectors are invited.

The photodiodes in this class of product are generally made from high-resistivity silicon; however, low-resistivity silicon is sometimes used depending on the application. The TIXL80 and TIXL98 are examples of the performance available using high-resistivity silicon. Pages 363 through 366 provide additional information on high-resistivity detectors.

The avalanche photodiode (APD) is a photodiode especially suited for low-noise applications where the principal noise source is the preamplifier. An APD has characteristics similar to a conventional photodiode with the addition of an internal linear current-gain mechanism due to the avalanche effect. The gain is determined by applied reverse bias just below the breakdown voltage of the diode. The gain, M, is controllable from 1 to the minimum value specified on the data sheet.

Signal current gain in the photodiode improves the sensitivity of the system by a factor that varies from equal to the gain up to the point where the noise caused by the bulk reverse current of the photodiode is comparable to that of the amplifier. This noise can be determined by multiplying the square of the shot-noise current by the avalanche gain raised to the power given in the data sheet. See Figure 1 of the data sheets for types TIXL55, TIXL56, TIXL59, TIXL69, TIXL83, or TIXL84. This exponent is typically 2.3 for these devices.

Amplifiers used with photodiodes are of particular importance in determining system sensitivity. A photodiode is in effect a current source and the amplifier input should be designed for such a signal while introducing minimal noise current. The output is normally a low-impedance voltage source. For frequency responses up to 10 MHz, an operational amplifier operated in the transimpedance mode is generally recommended. For frequencies above this, Texas Instruments provides the TIXL150, TIXL151, and TIXL152 transimpedance amplifiers with 100-MHz, 50-MHz, and 20-MHz bandwidths, respectively. Microwave photodetector systems normally use available standard low-noise 50-ohm-input amplifiers.

Photodetector modules are complete optical receiver assemblies. Those listed in this section contain a sensitive APD and a low-noise transimpedance amplifier. In addition they also contain an automatic bias circuit for constant-gain operation of the APD over a range of temperatures. These modules allow the incorporation of the sensitive APD's into systems with a minimum of cost.

sources and detectors for fiber-optics/optical waveguide coupling

A number of sources and detectors have been designed specifically for applications in fiber-optic communication and data transmission. These devices have in common a package design that couples directly to the CORNING™ T-19H optical waveguide connector, but can be adapted to other fiber-optic bundles. The products included in this category are:

Infrared-emitting diodes
Infrared-emitting transmitter modules
Avalanche photodiodes
Avalanche photodiode receiver modules

The infrared-emitting diodes (IRED's) are dome-shaped to couple more light into the 8° acceptance half-angle of low-loss optical waveguides. Coupling efficiency into standard 30° acceptance half-angle fiber-optic bundles is excellent. Peak infrared emission near 0.91 μm is well matched to the peak response of silicon photodetectors.

The transmitter module provides electronics to allow the infrared-emitting diode to be driven at high current levels by standard TTL logic circuits, while requiring only a five-volt power supply.

The avalanche photodiode (APD) is a photodiode especially suited for fiber-optic applications where long transmission lengths (ten to hundreds of yards or meters) result in very low optical power levels at the detector. In such low-noise applications where the principal noise source is the preamplifier, the avalanche gain will provide improved performance. Fiber-optic coupling to photodiodes is near optimum because the diode active area can be large enough to intercept the full cone of radiation from the fiber bundle and losses can be reduced to reflection only.

An avalanche-photodiode receiver module for fiber-optic applications consists of an APD in a fiber-optic-coupling package, together with a voltage regulator to provide temperature stabilization of the gain, and a low-noise transimpedance amplifier.

P-N PLANAR GALLIUM ARSENIDE INFRARED-EMITTING DIODE

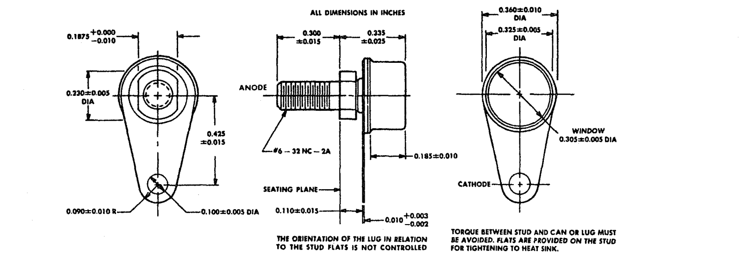
BULLETIN NO. DL-S 729723, FEBRUARY 1967—REVISED FEBRUARY 1972

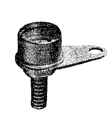
DESIGNED TO EMIT NEAR-INFRARED RADIATION WHEN FORWARD BIASED

- **Radiant energy source spectrally matched to silicon sensors**
- **High radiance**
- **Circular, consistent-size, flat emitting areas . . . 7.5 mils diameter**
- **Recommended for precision optical alignment, communication, and photographic film annotation**

mechanical data

This device is in a hermetically sealed package with a flat glass window in the top of the case. The cathode is in electrical contact with the case and adjacent solder lug. The anode is in electrical contact with the stud, which is insulated from the case by a glass-to-metal seal.





absolute maximum ratings

Reverse Voltage at 25°C Case Temperature	2 V
Continuous Forward Current at (or below) 25°C Case Temperature (See Note 1)	500 mA
Storage Temperature Range	−55°C to 125°C
Solder Lug Temperature for 10 Seconds (See Note 2)	240°C

operating characteristics at 25°C case temperature

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 500 mA	0.6	1.2		mW
λ_p	Wavelength at Peak Emission			0.91		μm
$\Delta\lambda$	Spectral Bandwidth			250		Å
θ_{HI}	Half-Intensity Beam Angle			115°		
V_F	Static Forward Voltage			1.7	2.3	V

NOTES: 1. Derate linearly to 125°C case temperature at the rate of 5 mA/°C.
2. Soldered connections should not be made directly to the stud because of the low-resistance path between the stud and emitting element.

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TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

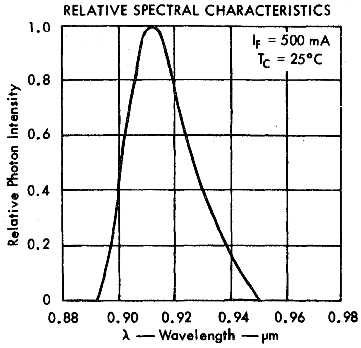

FIGURE 1

RELATIVE PHOTON INTENSITY vs ANGULAR DISPLACEMENT

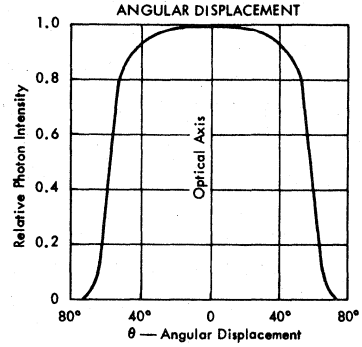

FIGURE 2

RELATIVE PHOTON INTENSITY vs CASE TEMPERATURE

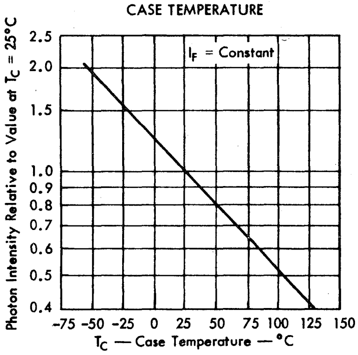

FIGURE 3

CHANGE IN WAVELENGTH OF PEAK INTENSITY vs CASE TEMPERATURE

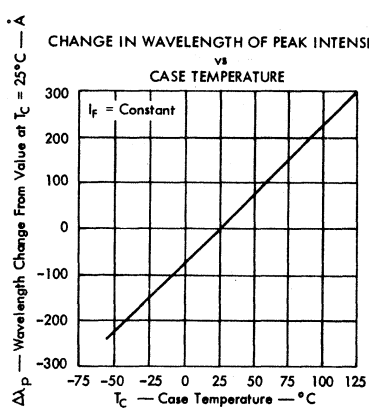

FIGURE 4

RELATIVE PHOTON INTENSITY vs FORWARD CURRENT

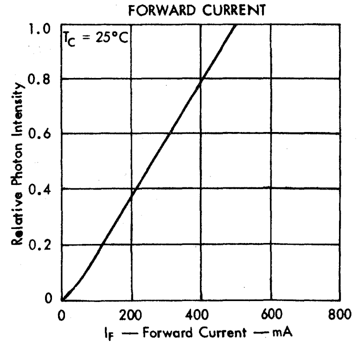

FIGURE 5

FORWARD CONDUCTION CHARACTERISTICS

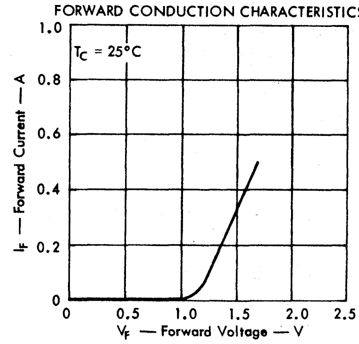

FIGURE 6

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P-N GALLIUM ARSENIDE INFRARED-EMITTING DIODES

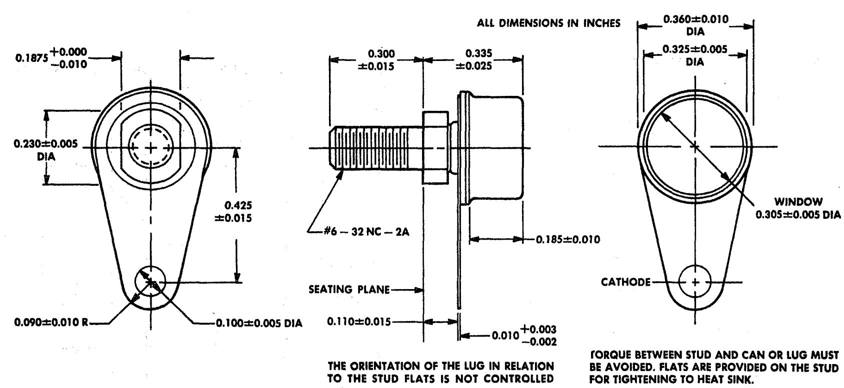
BULLETIN NO. DL-S 6911177, MARCH 1969

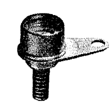
DESIGNED TO EMIT NEAR-INFRARED RADIATION WHEN FORWARD BIASED

- **High Output . . . 60 mW Min at 25°C for the TIXL14**
- **High Output Efficiency . . . 10% Min at 25°C for TIXL12**
- **Hemispherical Emitting Crystals with Diameters of 36 Mils for the TIXL12 and TIXL13, 72 Mils for the TIXL14 and TIXL15**
- **Spectrally Matched to Silicon Sensors**
- **Stud-Mounted Package for Convenient Mounting and Heat Sinking**

mechanical data

The devices are in hermetically sealed packages with a flat glass window in the top of the case. The cathode is in electrical contact with the case and adjacent solder lug. The anode is in electrical contact with the stud, which is insulated from the case by a glass-to-metal seal. Soldered connections should not be made directly to the stud because of the low thermal-resistance path between the stud and emitting element.





absolute maximum ratings

	TIXL12 TIXL13	TIXL14 TIXL15
Reverse Voltage at 25°C Case Temperature	2 V	2 V
Continuous Forward Current at (or below) 25°C Case Temperature (See Note 1)	300 mA	1 A
Storage Temperature Range	−55°C to 100°C	
Solder Lug Temperature for 10 Seconds	←240°C→	

operating characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TYPE	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	TIXL12 and TIXL13: I_F = 300 mA	TIXL12	40	50		mW
			TIXL13	20	30		mW
			TIXL14	60	75		mW
			TIXL15	30	50		mW
λ_p	Wavelength at Peak Emission	TIXL14 and TIXL15: I_F = 1 A	All		0.93		μm
$\Delta\lambda$	Spectral Bandwidth		All		450		Å
θ_{HI}	Half-Intensity Beam Angle		All		130°		
V_F	Static Forward Voltage		All		1.4	2	V

NOTE 1: Derate linearly to 100°C case temperature at the rate of 4 mA/°C for the TIXL12 and TIXL13, 13.3 mA/°C for the TIXL14 and TIXL15.

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PRELIMINARY DATA SHEET: Supplementary data may be published at a later date.

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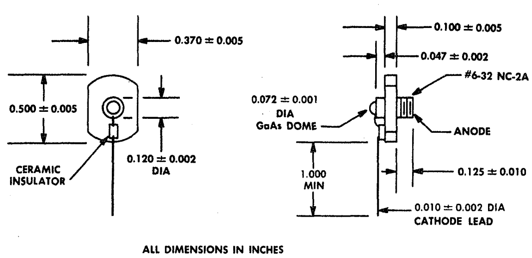
BULLETIN NO. DL-S 7412208, NOVEMBER 1974

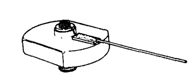
DESIGNED TO EMIT NEAR-INFRARED RADIATION WHEN FORWARD BIASED

- High Output Power . . . 100 to 350 mW Min at 25°C
- Hemispherical Emitter with a Diameter of 72 mils
- Stud Mounting for Convenient Heat Sinking
- Open Construction to Allow Flexibility in Optical Design
- TIXL16B Was Formerly TIXL16

mechanical data

These diodes are mounted on copper stud headers to provide efficient heat sinking. The anodes are in electrical contact with the copper studs. The cathode leads are varnished 0.01-inch copper wires secured to the studs by metalized ceramic insulators. Soldered connections should not be made directly to the stud because of the low-thermal-resistance path to the emitting element.





absolute maximum ratings

	TIXL16A TIXL16B	TIXL16C
Reverse Voltage at 25°C Stud Temperature	2 V	2V
Continuous Forward Current at (or below) 25°C Stud Temperature (See Note 1)	2 A	3A
Storage Temperature Range	−55°C to 100°C	
Lead Temperature ¼ Inch from Ceramic Insulator for 5 Seconds	←230°C→	

operating characteristics at 25°C stud temperature

PARAMETER	TEST CONDITIONS	TIXL16A			TIXL16B			TIXL16C			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
P_O Radiant Power Output	I_F = 2 A for TIXL16A and TIXL16B, 3 A for TIXL16C	100	150		200	230		350	400		mW
λ_p Wavelength at Peak Emission			0.93			0.93			0.94		μm
$\Delta\lambda$ Spectral Bandwidth			450			450			450		Å
θ_{HI} Half-Intensity Beam Angle			150°			150°			150°		
V_F Static Forward Voltage			1.6	2		1.6	2		1.8	2.2	V

NOTE: 1. Derate linearly to 100°C stud temperature at the rate of 26.7 mA/°C for TIXL16A and TIXL16B, 40 mA/°C for TIXL16C.

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P-N GALLIUM ARSENIDE INFRARED-EMITTING DIODE

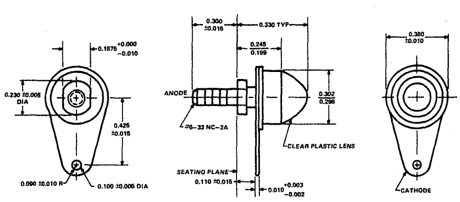
BULLETIN NO. DL-S 7111566, SEPTEMBER 1971

DESIGNED TO EMIT NEAR-INFRARED RADIATION WHEN FORWARD BIASED

- **High Output Power . . . 15 mW Min at 25°C**
- **Spectrally Matched to Silicon Sensors**
- **Stud Mounting for Convenient Heat Sinking**
- **Recommended for Precision Optical Alignment, Industrial Controls, and Optical Communications**

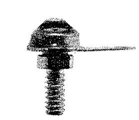
mechanical data

The device is encapsulated and mounted on a stud header. The cathode is in electrical contact with the solder lug. The anode is in electrical contact with the stud, which is insulated from the case by a glass-to-metal seal. Soldered connections should not be made directly to the stud because of the low-thermal-resistance path between stud and emitting element.



NOTES: A. The orientation of the lug in relation to the stud flats is not controlled.
B. Torque between stud and lug must be avoided. Flats are provided on the stud for tightening to heat sink.

ALL DIMENSIONS IN INCHES



absolute maximum ratings

Reverse Voltage at 25°C Stud Temperature . . . . 2 V
Continuous Forward Current at (or below) 25°C Stud Temperature (See Note 1) . . . . 300 mA
Operating Stud Temperature Range . . . . 0°C to 70°C
Storage Temperature Range . . . . −50°C to 90°C
Solder Lug Temperature for 10 Seconds . . . . 240°C

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operating characteristics at 25°C stud temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	$I_F = 300$ mA	15	20		mW
λ_p	Wavelength at Peak Emission			0.94		μm
$\Delta\lambda$	Spectral Bandwidth			450		Å
θ_{HI}	Half-Intensity Beam Angle			135°		
V_F	Static Forward Voltage			1.7	2.2	V

NOTE 1: Derate linearly to 70°C stud temperature at the rate of 6.7 mA/°C.

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TYPICAL CHARACTERISTICS

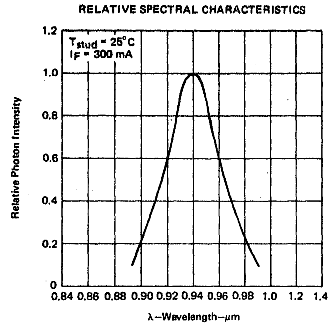

FIGURE 1

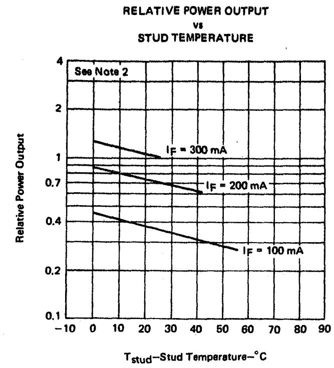

FIGURE 2

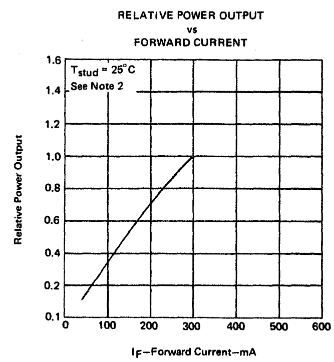

FIGURE 3

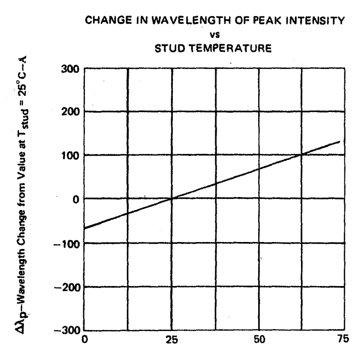

FIGURE 4

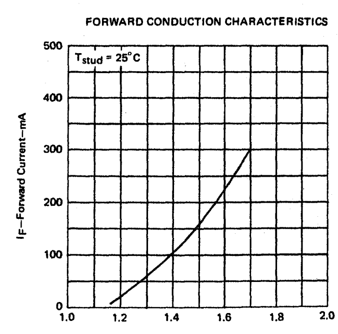

FIGURE 5

NOTE 2: These curves have been normalized to the output at I_F = 300 mA, T_{stud} = 25°C.

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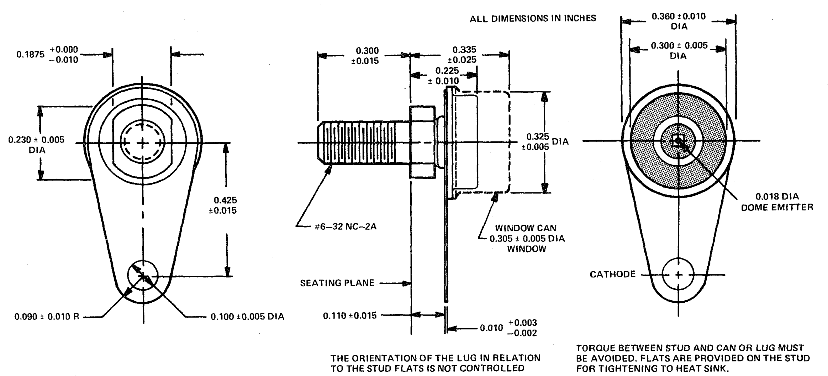
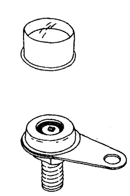
DESIGNED TO EMIT NEAR-INFRARED RADIATION WHEN FORWARD BIASED

- **High Speed, High Efficiency**
- **Hemispherically Shaped 0.018-Inch Chip Diameter**
- **Stud Mounting for Convenient Heat Sinking**

mechanical data

The cathode is in electrical contact with the case and adjacent solder lug. The anode is in electrical contact with the stud, which is insulated from the case by a glass-to-metal seal. Soldered connections should not be made directly to the stud because of the low-thermal-resistance path between the stud and emitting element. The window can is not sealed to the header.





absolute maximum ratings

Reverse Voltage at 25°C Case Temperature . . . . . 2 V
Continuous Forward Current at (or below) 25°C Case Temperature (See Note 1) . . . . . 200 mA
Storage Temperature Range . . . . . −55°C to 100°C
Solder Lug Temperature for 10 Seconds . . . . . 240°C

operating characteristics at 25°C case temperature (without window can in place)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 50 mA	900	1200		μW
λ_p	Wavelength at Peak Emission			0.91		μm
$\Delta\lambda$	Spectral Bandwidth			300		Å
θ_{HI}	Half-Intensity Beam Angle			135°		
V_F	Static Forward Voltage			1.5	2	V
t_r	Radiant Pulse Rise Time†	I_{FM} = 50 mA, t_w = 100 ns, f = 100 kHz		10		ns

†Radiant pulse rise time is the time required for a change in radiant power output from 10% to 90% of its peak value for a step change in current.

NOTE 1: Derate linearly to 50 mA at 100°C case temperature at the rate of 2.0 mA/°C.

1

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P-N GALLIUM ARSENIDE INFRARED-EMITTING DIODE

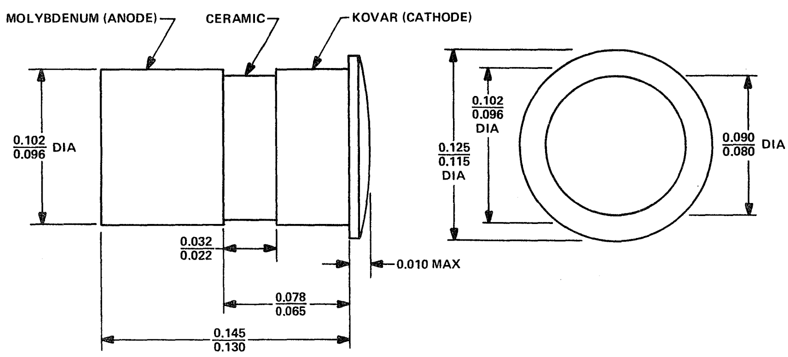
BULLETIN NO. DL-S 7412212, NOVEMBER 1974

DESIGNED TO EMIT NEAR-INFRARED RADIATION WHEN FORWARD BIASED

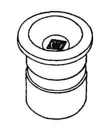
- Dome-Shaped 0.018-Inch-Diameter Chip
- Built-In Reflector
- Fast Rise Time, High Efficiency

mechanical data

The reflector cavity is filled with clear epoxy.



DIMENSIONS ARE IN INCHES



4 TIMES ACTUAL SIZE

absolute maximum ratings

Reverse Voltage at 25°C Case Temperature	2 V
Continuous Forward Current at (or below) 25°C Case Temperature (See Note 1)	150 mA
Storage Temperature Range	−55°C to 100°C
Soldering Temperature for 10 Seconds	240°C

operating characteristics at 25°C case temperature

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 50 mA	1			mW
λ_p	Wavelength at Peak Emission			0.91		μm
$\Delta\lambda$	Spectral Bandwidth			300		Å
θ_{HI}	Half-Intensity Beam Angle			25°		
V_F	Static Forward Voltage			1.5	2	V
t_r	Radiant Pulse Rise Time†	I_{FM} = 50 mA, t_w = 100 ns, f = 100 kHz		10		ns

†Radiant pulse rise time is the time required for a change in radiant power output from 10% to 90% of its peak value for a step change in current.

NOTE 1: Derate linearly to 50 mA at 100°C case temperature at the rate of 1.33 mA/°C.

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BULLETIN NO. DL-S 7610606, JUNE 1968–REVISED MARCH 1976

OPTIMIZED FOR HIGH-SPEED DETECTION OF NEAR-INFRARED RADIATION

- **Useful from Audio to Microwave Frequencies**
- **Typical Photocurrent Gain of >600**
- **Active Area of 5 X 10^{-4} cm^2**
- **Typical Gain-Bandwidth Product† of 80 GHz**
- **Typical System Noise Equivalent Power of 10^{-12} W/$\sqrt{Hz}$ at 1 GHz**
- **Pill-Package design allows mounting in Coaxial and Stripline Microwave Structures**

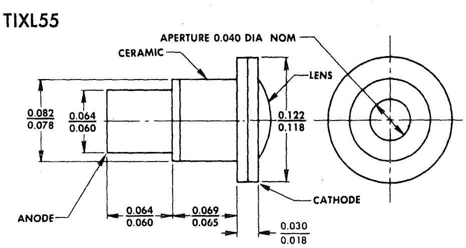
description

The TIXL55 and TIXL56 are high-speed photodiodes used for engineering evaluation and designed to operate in the avalanche region. Photocurrent gain results from avalanche multiplication and provides excellent low-noise performance over wide bandwidths.

mechanical data

The devices are in hermetically sealed packages with glass window. The outline of the TIXL56 is similar to TO-18 except for the window. All TO-18 registration notes also apply to this outline.

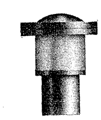
TIXL55



THE LENS IS BOROSILICATE GLASS. ITS FOCAL LENGTH IS 0.110 REFERENCED TO THE TOP OF THE FLANGE.

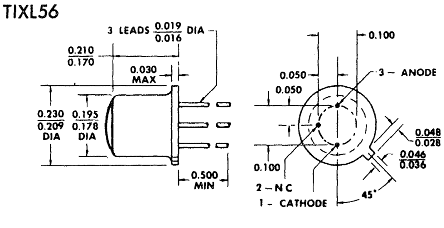
THE ACTIVE SURFACE IS 0.035 BELOW THE TOP OF THE FLANGE. ITS DIAMETER IS 0.010.

ALL DIMENSIONS ARE IN INCHES



4 TIMES ACTUAL SIZE

TIXL56

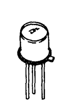


THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE.

MAXIMUM WINDOW EXTENSION FROM TOP OF CASE IS 0.040, MINIMUM DIAMETER IS 0.125

THE LENS IS BOROSILICATE GLASS.

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



absolute maximum ratings

Continuous Power Dissipation at (or below) 25°C Case Temperature (See Note 1)	100 mW
Operating Case Temperature Range	−65°C to 125°C
Soldering Temperature for 3 Minutes (TIXL55)	240°C
Lead Temperature 1/16 Inch from Case for 10 Seconds (TIXL56)	300°C

NOTE 1: Derate linearly to 125°C case temperature at the rate of 1 mW/°C.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

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electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS§	MIN	TYP	MAX	UNIT
Breakdown Voltage, $V_{(BR)}$		I_R = 100 µA, E_e = 0	155	170	185	V
Dark Current‡	Bulk	M = 100, E_e = 0		5	30	pA
	Surface			0.8	10	nA
Temperature Coefficient of Breakdown Voltage		I_R = 100 µA, E_e = 0, See Note 2		200		mV/°C
Photocurrent Gain at Avalanche Noise Threshold, M_T		λ = 0.9 µm, See Note 3	200	>600		
Total Capacitance, C_T		V_R = 100 V, f = 1 MHz		1.2	3	pF
Series Resistance		f = 0.9 GHz		50		Ω
Gain-Bandwidth Product†		f_{mod} = 1 GHz, λ = 6328 Å		80		GHz
Radiant Responsivity, R_e		λ = 0.9 µm, M = 100, f_{mod} = 15 MHz, $\Phi_e \leq$ 0.1 mW	15	20		A/W

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.
‡Dark current is the sum of surface current and gain M times the bulk current.
§E_e is the incident radiant power per unit area.

NOTES: 2. Temperature coefficient is determined by the formula:

$$\text{Temperature coefficient} = \frac{V_{(BR)} @ 125°C - V_{(BR)} @ -55°C}{125°C - (-55°C)}$$

3. Gain M_T is measured at the reverse voltage at which the noise deviates from the theoretical linear characteristic. See Figure 1. Radiant flux is as required to give a photocurrent of 0.1 nA rms at V_R = 40 V.

TYPICAL CHARACTERISTICS

SIGNAL POWER AND NOISE POWER vs PHOTOCURRENT GAIN

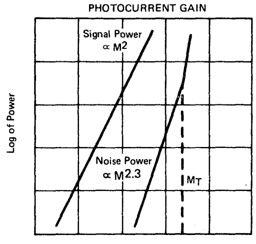

FIGURE 1

PHOTOCURRENT GAIN vs REVERSE VOLTAGE

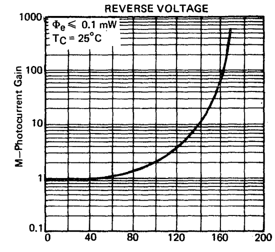

FIGURE 2

RADIANT RESPONSIVITY vs WAVELENGTH

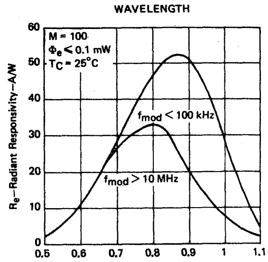

FIGURE 3

TOTAL CAPACITANCE vs REVERSE VOLTAGE

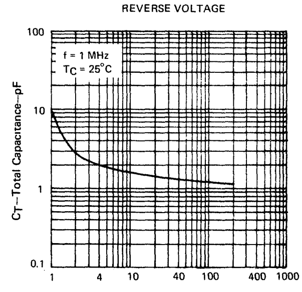

FIGURE 4

BIBLIOGRAPHY: Biard, J.R. and W.N. Shaunfield: A Model of the Avalanche Photodiode, *IEEE Transactions on Electron Devices,* vol. ED-14, no. 5, pp. 233-238, May 1967.

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TYPE TIXL59
SILICON AVALANCHE PHOTODIODE

BULLETIN NO. DL-S 7411287, JUNE 1971—REVISED NOVEMBER 1974

OPTIMIZED FOR HIGH-SPEED DETECTION OF NEAR-INFRARED RADIATION

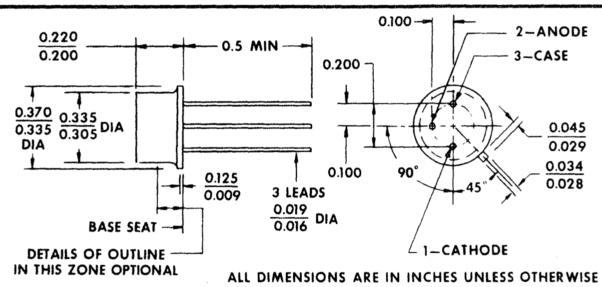
- **Isolated Case for Shielding**
- **Useful from Audio to Microwave Frequencies**
- **Minimum Photocurrent Gain of 200**
- **Active Area of 4.5 X 10^{-3} cm^2 (Diameter = 0.030 in)**
- **Typical Gain-Bandwidth Product† of 80 GHz**
- **Typical System Noise Equivalent Power of 2 X 10^{-13} $W/\sqrt{Hz}$ at 30-MHz Bandwidth**

description

The TIXL59 is a high-speed photodiode intended for engineering evaluation. This device is designed to operate in the avalanche region to provide gain for excellent low-noise performance over wide performance over wide bandwidths. The TIXL59 is similar to TIXL56 except that it has a larger active area making it more useful in lens systems with smaller f-numbers or where focusing is a problem.

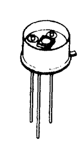
mechanical data

The device is in a hermetically sealed welded case similar to, but slightly shorter than, JEDEC TO-5 with window. All TO-5 registration notes also apply to this outline. The lens is borosilicate glass. Its nominal dimensions are: diameter, 0.305 inch; thickness, 0.060 inch; and distance from front surface of the lens to the active area, 0.085 inch.



ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE



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absolute maximum ratings

Continuous Power Dissipation at (or below) 25°C Case Temperature (See Note 1)	100 mW
Operating Case Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	230°C

NOTE: 1. Derate linearly to 125°C case temperature at the rate of 1 mW/°C.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

TYPE TIXL59
SILICON AVALANCHE PHOTODIODE

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS§		MIN	TYP	MAX	UNIT
Breakdown Voltage, $V_{(BR)}$		I_R = 100 μA,	E_e = 0	155	170	185	V
Dark Current‡	Bulk	M = 100,	E_e = 0		60	150	pA
	Surface				2	20	nA
Temperature Coefficient of Breakdown Voltage		I_R = 100 μA, See Note 2	E_e = 0,		200		mV/°C
Photocurrent Gain at Avalanche Noise Threshold, M_T		λ = 0.9 μm,	See Note 3	200	>600		
Total Capacitance, C_T		V_R = 100 V,	f = 1 MHz		8.5	12	pF
Series Resistance		f = 0.9 GHz			5		Ω
Gain-Bandwidth Product†		f_{mod} = 1 GHz,	λ = 6328 Å		80		GHz
Radiant Responsivity, R_e		λ = 0.9 μm, f_{mod} = 15 MHz,	M = 100, $\Phi_e \leqslant$ 0.1 mW	15	20		A/W

NOTES: 2. Temperature coefficient is determined by the formula: $$\text{Temperature coefficient} = \frac{V_{(BR)} @ 125°C - V_{(BR)} @ -55°C}{125°C - (-55°C)}$$

3. Gain M_T is measured at the reverse voltage at which the noise deviates from the theoretical linear characteristic. See Figure 1. Radiant flux is as required to give a photocurrrent of 0.1 nA rms at V_R = 40 V.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

‡Dark current is the sum of surface current and gain M times the bulk current. §E_e is the incident radiant power per unit area.

TYPICAL CHARACTERISTICS

SIGNAL POWER AND NOISE POWER vs PHOTOCURRENT GAIN

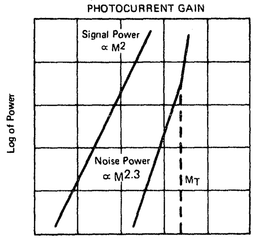

FIGURE 1

PHOTOCURRENT GAIN vs REVERSE VOLTAGE

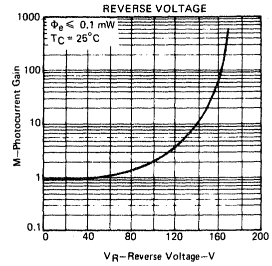

FIGURE 2

10

RADIANT RESPONSIVITY vs WAVELENGTH

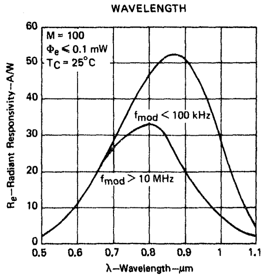

FIGURE 3

TOTAL CAPACITANCE vs REVERSE VOLTAGE

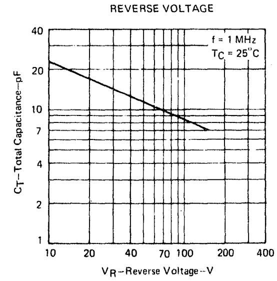

FIGURE 4

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BULLETIN NO. DL-S 7411685, FEBRUARY 1972–REVISED NOVEMBER 1974

OPTIMIZED FOR HIGH-SPEED DETECTION OF NEAR-INFRARED RADIATION

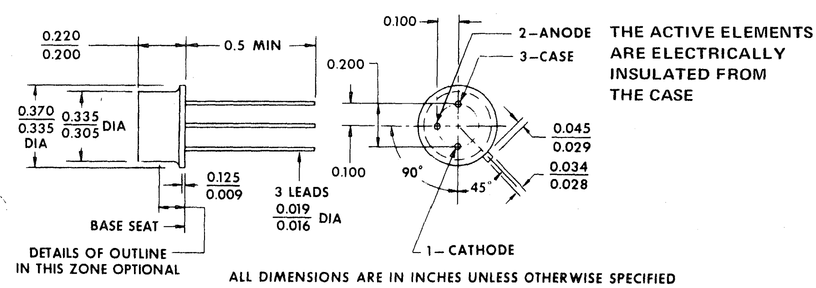
- Useful from Audio to Microwave Frequencies
- Typical Photocurrent Gain of >600
- Active Area of 1.8 X 10^{-2} cm^2 (Dia. = 0.060")
- Typical Gain-Bandwidth Product† of 80 GHz
- Typical System Noise Equivalent Power of 2 X 10^{-13} $W/\sqrt{Hz}$ at 30-MHz Bandwidth with TIXL151 Amplifier

description

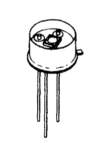
The TIXL69 is a high-speed photodiode available for engineering evaluation. This device is designed to operate in the avalanche region to provide gain for excellent low-noise performance over wide bandwidths. The TIXL69 is similar to the TIXL56 and TIXL59 except that it has a larger active area.

mechanical data

The device is in a hermetically sealed welded case similar to, but slightly shorter than, JEDEC TO-5 with window. All TO-5 registration notes also apply to this outline. The lens is borosilicate glass. Nominal lens dimensions are: diameter, 0.305 inch; thickness, 0.060 inch; and distance from front surface of the lens to the active area, 0.075 inch.



ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



absolute maximum ratings

Continuous Power Dissipation at (or below) 25°C Case Temperature (See Note 1)	100 mW
Operating Case Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

NOTE 1: Derate linearly to 125°C case temperature at the rate of 1 mW/°C.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

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electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS§		MIN	TYP	MAX	UNIT
Breakdown Voltage, $V_{(BR)}$		I_R = 100 μA,	E_e = 0	155	170	185	V
Dark Current‡	Bulk	M = 100,	E_e = 0		140	700	pA
	Surface				3.5	40	nA
Temperature Coefficient of Breakdown Voltage		I_R = 100 μA, See Note 2	E_e = 0,		200		mV/°C
Photocurrent Gain at Avalanche Noise Threshold, M_T		λ = 0.9 μm,	See Note 3	200	>600		
Total Capacitance, C_T		V_R = 100 V,	f = 1 MHz		30	45	pF
Series Resistance		f = 0.9 GHz			5		Ω
Gain-Bandwidth Product†		f_{mod} = 1 GHz,	λ = 6328 Å		80		GHz
Radiant Responsivity, R_e		λ = 0.9 μm, f_{mod} = 15 MHz,	M = 100, $\Phi_e \leqslant 0.1$ mW	15	20		A/W

NOTES: 2. Temperature coefficient is determined by the formula:

$$\text{Temperature coefficient} = \frac{V_{(BR)} @ 125°C - V_{(BR)} @ -55°C}{125°C - (-55°)}$$

3. Gain M_T is measured at the reverse voltage at which the noise deviates from the theoretical linear characteristic. See Figure 1. Radiant flux is as required to give a photocurrent of 0.1 nA rms at V_R = 40 V.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

‡Dark Current is the sum of surface current and gain M times the bulk current.

§E_e is the incident radiant power per unit area.

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TEXAS INSTRUMENTS
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TYPICAL CHARACTERISTICS

SIGNAL POWER AND NOISE POWER
vs
PHOTOCURRENT GAIN

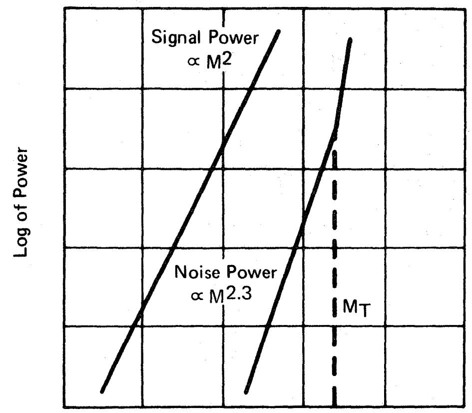

FIGURE 1

PHOTOCURRENT GAIN
vs
REVERSE VOLTAGE

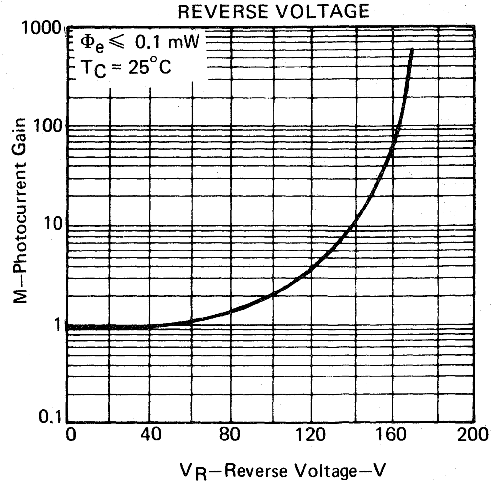

FIGURE 2

RADIANT RESPONSIVITY
vs
WAVELENGTH

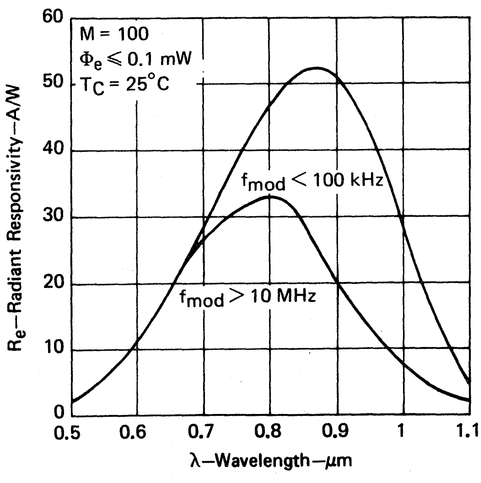

FIGURE 3

TOTAL CAPACITANCE
vs
REVERSE VOLTAGE

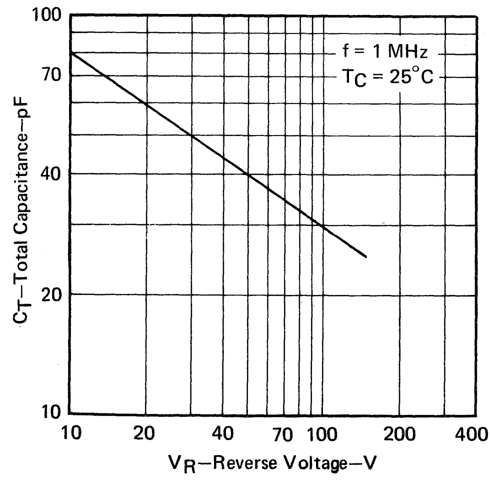

FIGURE 4

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BULLETIN NO. DL-S 7111562, NOVEMBER 1971

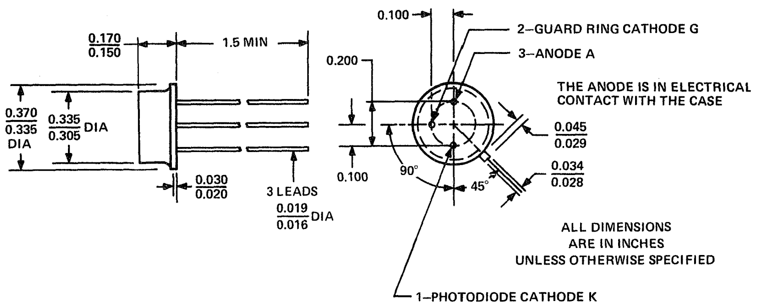
- Typical Responsivity . . . 0.6 A/W at 0.9 Microns
- Diameter of Active Area . . . 0.100 in
- Rise and Fall Time . . . 15 ns Typ at V_R = 100 V
- Dark Current . . . 15 nA Typ at V_R = 100 V
- Low Capacitance . . . 4.5 pF Typ at V_R = 100 V

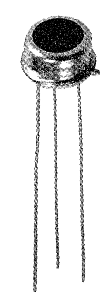
description

The TIXL80 is a high-speed silicon photodiode. The device is designed to operate in a reverse-bias mode to provide low capacitance with high speed and high responsivity. The device utilizes a guard-ring structure to provide excellent low noise characteristics. A 0.100-inch-diameter aperature located approximately 0.030 inch from the surface of the active area prevents extraneous illumination and provides a plane for focusing.

mechanical data

The TIXL80 is in a hermetically sealed welded case similar to, but shorter than, JEDEC TO-5 with window. The lens is made of borosilicate glass with a nominal thickness of 0.050 inch. Approximate weight is 1.2 grams.





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absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Forward Voltage	0.5 V
Reverse Voltage	200 V
Continuous Power Dissipation at (or below) 25°C Case Temperature (See Note 1)	100 mW
Operating Case Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

NOTE 1: Derate linearly to 125°C case temperature at the rate of 1 mW/°C.

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electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)}$	Breakdown Voltage	I_R = 100 µA, E_e = 0, See Note 2	200			V
I_D	Dark Current	V_R = 15 V, E_e = 0, See Note 2		10		nA
		V_R = 100 V, E_e = 0, See Note 2		15	500	
C_T	Total Capacitance	V_R = 15 V, f = 1 MHz		8.5		pF
		V_R = 100 V, f = 1 MHz		4.5	5.5	
R_e	Radiant Responsivity	V_R = 15 V, λ = 0.9 µm		0.6		A/W
		V_R = 100 V, λ = 0.9 µm	0.4	0.6		
		V_R = 15 V, λ = 1.06 µm		0.20		
		V_R = 100 V, λ = 1.06 µm		0.20		

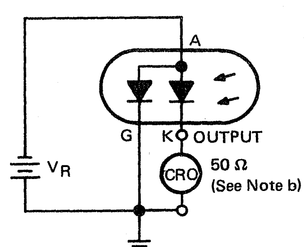
NOTE 2: Irradiance (E_e) is the radiant power per unit area incident on a surface.

switching characteristics at 25°C case temperature

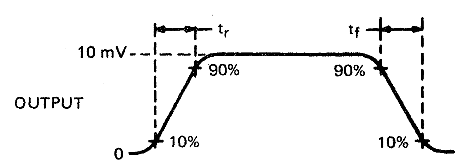
PARAMETER		TEST CONDITIONS		TYPICAL	UNIT
t_r	Rise Time	I_L = 200 µA, R_L = 50 Ω, See Note 3 and Figure 1	V_R = 100 V	15	ns
			V_R = 15 V	50	
t_f	Fall Time		V_R = 100 V	15	ns
			V_R = 15 V	50	

NOTE 3: Input irradiance is supplied by a pulsed GaAs laser (λ = 0.9 µm). Rise and fall times are shorter for 1.06-µm irradiation.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORM

NOTES: a. Incident irradiation is adjusted for I_L = 200 µA.
b. The output waveform is monitored on a oscilloscope with the following characteristics: $t_r \leq 2.5$ ns, R_{in} = 50 Ω.

FIGURE 1—SWITCHING TIMES

TYPICAL CHARACTERISTICS

DARK CURRENT
vs
CASE TEMPERATURE

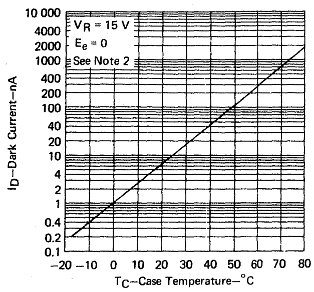


FIGURE 2

REVERSE CURRENT
vs
REVERSE VOLTAGE

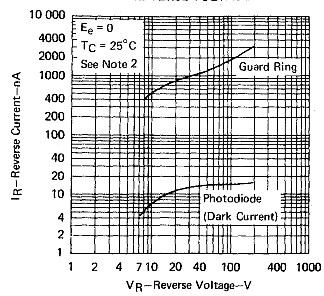


FIGURE 3

CAPACITANCE
vs
REVERSE VOLTAGE

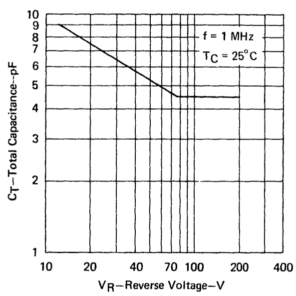


FIGURE 4

RESPONSIVITY
vs
WAVELENGTH

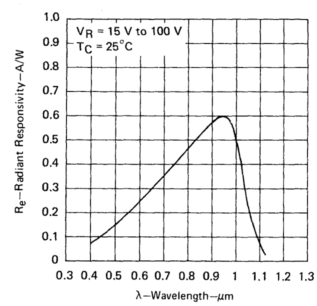


FIGURE 5

QUANTUM EFFICIENCY
vs
CASE TEMPERATURE

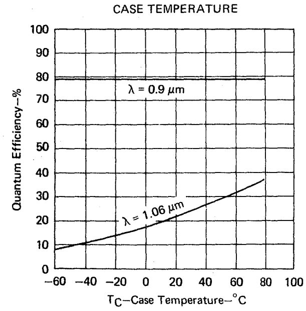


FIGURE 6

RISE AND FALL TIMES
vs
REVERSE VOLTAGE

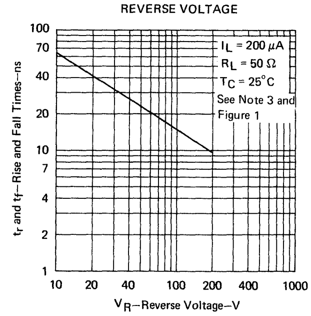


FIGURE 7

NOTES: 2. Irradiance (E_e) is the radiant power per unit area incident on a surface.
3. Input irradiance is supplied by a pulsed GaAs laser (λ = 0.9 μm). Rise and fall times are shorter for 1.06-μm irradiation.

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TEXAS INSTRUMENTS
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LARGE-AREA QUADRANT-GEOMETRY SILICON PHOTODIODE

BULLETIN NO. DL-S 7612191, NOVEMBER 1974—REVISED MARCH 1976

- **Quadrant Geometry . . . For Alignment and Tracking Applications**
- **Diameter of Active Area . . . 0.650 Inch**
- **Rise and Fall Times . . . 7 ns Typ at 1.06 μm Wavelength**
- **Dark Current . . . 100 nA Typ per Quadrant**
- **Radiant Responsivity . . . 0.34 A/W Typ at λ = 1.06 μm, 0.68 A/W Typ at λ = 0.9 μm**
- **Sensitive to Wavelengths from 0.60 μm to 1.06 μm**

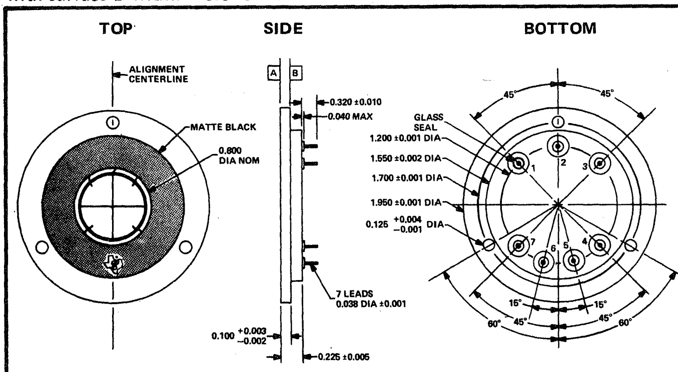
description

The TIXL82 is a high-speed, quadrant-geometry, high-resistivity silicon photodiode. It is a precision device designed specifically for application in laser alignment and guidance systems. A guard-ring structure is utilized to provide excellent low-noise characteristics, while operation in the fully depleted mode results in high speed and high radiant responsivity. Crosstalk between any two quadrants is less than five percent. Anti-reflection coatings on the window and the photodiode surface, normally peaked for 1.06 μm wavelength, can be adjusted to customer specification.

mechanical data

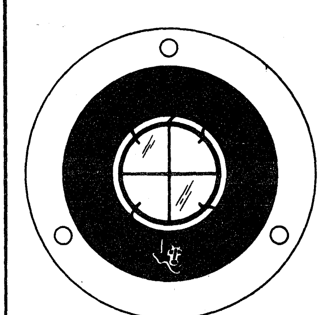
The hermetic package is a precision gold-plated brass case with an epoxy-sealed, AR-coated 0.040-inch-thick glass window. The window is limited by a flat-black aperature ring to a clear diameter of 0.80 inch. Approximate weight is 45 grams.

The center of the active area is located within a radial distance of 0.001 inch from the center of the circle defined by the outer diameter of the case. Oriented as shown, the vertical quadrant separator line is parallel to a line passing through the center of the case and through the mounting hole center within a tolerance of 1°. The surface of the active area is located 0.100 ± 0.010 inch below the top surface of the case (surface A in the outline drawing) and coplanar with surface B within ±0.010 inch.



1 QUADRANT I CATHODE
2 GUARD RING CATHODE
3 QUADRANT II CATHODE
4 QUADRANT III CATHODE
5 COMMON ANODE
6 CASE
7 QUADRANT IV CATHODE

All dimensions are in inches unless otherwise noted.
The active elements are electrically insulated from the case.



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TENTATIVE DATA SHEET

This document provides tentative information on a product in the developmental stage. Texas Instruments reserves the right to change or discontinue this product without notice.

TYPE TIXL82
LARGE-AREA QUADRANT-GEOMETRY SILICON PHOTODIODE

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Forward Voltage	0.5 V
Reverse Voltage	250 V
Continuous Power Dissipation per Quadrant at (or below) 25°C Case Temperature (See Note 1)	500 mW
Operating Case Temperature Range	−65°C to 100°C
Storage Temperature Range	−65°C to 125°C
Lead Temperature 1/16 inch from Case for 10 Seconds	300°C

NOTE 1: Derate linearly to 125 mW at 100°C case temperature at the rate of 5 mW/°C.

electrical characteristics at 25°C case temperature, each quadrant (see note 2)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)}$	Breakdown Voltage	I_R = 100 μA, E_e = 0, See Note 3	250			V
I_D	Dark Current	V_R = 180 V, E_e = 0, See Note 3		100	1000	nA
C_T	Total Capacitance	V_R = 180 V, f = 1 MHz		15	20	pF
R_e	Radiant Responsivity	V_R = 180 V, λ = 0.9 μm, f_{mod} = 400 Hz		0.68		A/W
		V_R = 180 V, λ = 1.06 μm, f_{mod} = 400 Hz		0.34		
	Crosstalk†	V_R = 180 V			0.05	

NOTES: 2. During tests of each quadrant, the other quadrants should be connected to the guard ring as shown in the switching circuit, Figure 1, except for the breakdown voltage and crosstalk measurements. For the measurement of breakdown voltage, the quadrant outputs are connected in parallel. For crosstalk, the outputs from the illuminated quadrant and one dark quadrant are read while the remaining quadrants are connected to the guard ring.

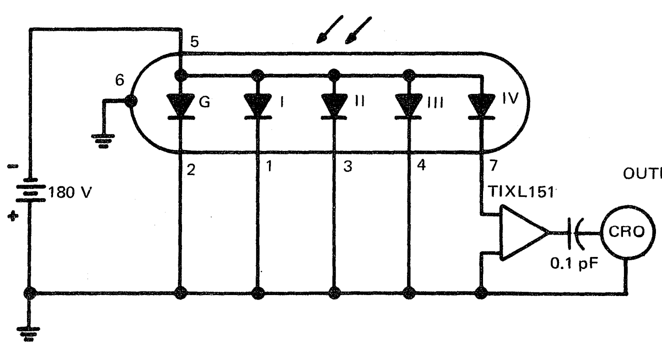
3. Irradiance (E_e) is the radiant power per unit area incident on a surface.

†This is the response of the one dark quadrant relative to one illuminated quadrant.

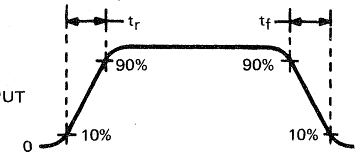
switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
t_r	Rise Time	V_R = 180 V, I_L = 20 μA, See Figure 1	λ = 0.9 μm		15		ns
			λ = 1.06 μm		7		
t_f	Fall Time		λ = 0.9 μm		15		ns
			λ = 1.06 μm		7		

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORM

NOTES: a. Input irradiance is supplied by a pulsed GaAs laser (λ = 0.9 μm). Incident irradiation is adjusted for I_L = 20 μA.
b. The output waveform is monitored on a oscilloscope with the following characteristics: $t_r \leqslant 2.5$ ns, R_{in} = 50 Ω.

FIGURE 1–SWITCHING TIMES

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TYPICAL CHARACTERISTICS†

DARK CURRENT vs CASE TEMPERATURE

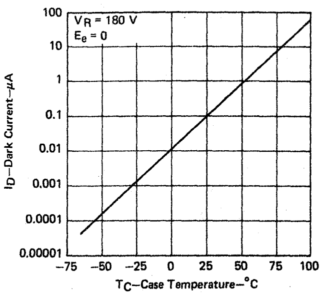

FIGURE 2

DARK CURRENT vs REVERSE VOLTAGE

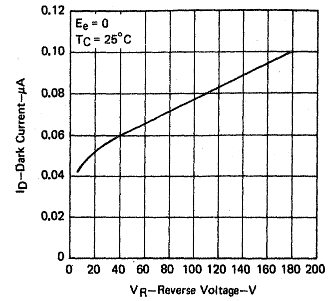

FIGURE 3

TOTAL CAPACITANCE vs REVERSE VOLTAGE

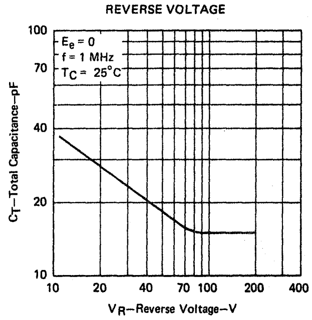

FIGURE 4

RADIANT RESPONSIVITY vs WAVELENGTH

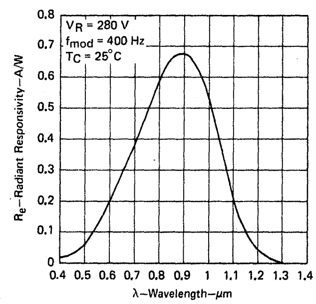

FIGURE 5

RADIANT RESPONSIVITY vs CASE TEMPERATURE

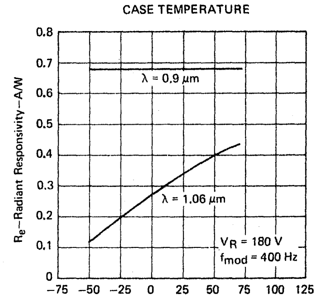

FIGURE 6

RISE and FALL TIMES vs REVERSE VOLTAGE

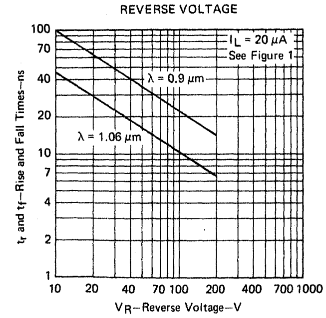

FIGURE 7

1

†Each quadrant was measured independently, but the characteristics apply as well to each quadrant when all are operated simultaneously.

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BULLETIN NO. DL-S 7412199, NOVEMBER 1974

OPTIMIZED FOR HIGH-SPEED DETECTION OF VISIBLE LIGHT

- Useful from Audio to Microwave Frequencies
- Typical Photocurrent Gain of >600
- Choice of Active Areas . . . 0.010 Inch Dia (TIXL83) or 0.030 Inch Dia (TIXL84)
- Typical Gain-Bandwidth Product† of 80 GHz
- Typical System Noise Equivalent Power Spectral Density of 2 X 10^{-13} W/$\sqrt{Hz}$ at 30 MHz Bandwidth
- TIXL84 Has Isolated Case for Shielding

description

The TIXL83 and TIXL84 are high-speed photodiodes intended for engineering evaluation. These devices are designed to operate in the avalanche region to provide gain for excellent low-noise performance over wide bandwidths. The TIXL83 and TIXL84 are similar to the TIXL56 and TIXL59, respectively, except that they are optimized for high-speed detection of visible light.

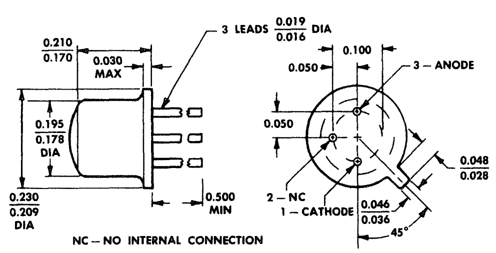
mechanical data

The devices are in hermetically sealed packages with windows of borosilicate glass.

The outline for the TIXL83 is similar to JEDEC TO-18 except for the window, and all TO-18 registration notes also apply to this outline. The nominal dimensions for the lens of the TIXL83 are: diameter, 0.155 inch; thickness, 0.045 inch; and distance from front surface of the lens to the active area, 0.140 inch.

The outline for the TIXL84 is similar to, but slightly shorter than, JEDEC TO-5 with window, and all TO-5 registration notes also apply to this outline. The nominal dimensions for the lens of the TIXL84 are: diameter, 0.305 inch; thickness, 0.050 inch; and distance from front surface of the lens to the active area, 0.085 inch.

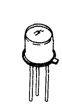
TIXL83



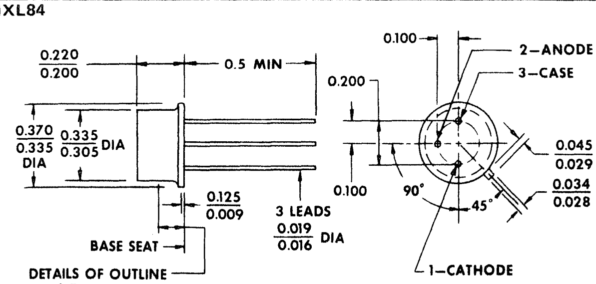
THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE

MAXIMUM WINDOW EXTENSION FROM TOP OF CASE IS 0.040
MINIMUM DIAMETER IS 0.150

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

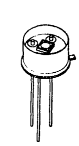


TIXL84



THE ACTIVE ELEMENTS ARE ELECTRICALLY INSULATED FROM THE CASE

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

TENTATIVE DATA SHEET
This document provides tentative information on a new product. Texas Instruments reserves the right to change specifications for this product in any manner without notice.

TEXAS INSTRUMENTS
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absolute maximum ratings

Continuous Power Dissipation at (or below) 25°C Case Temperature (See Note 1) . . . . 100 mW
Operating Case Temperature Range . . . . −65°C to 125°C
Storage Temperture Range . . . . −65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds . . . . 300°C

NOTE: 1 Derate linearly to 125°C case temperature at the rate of 1 mW/°C.

electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS§	TIXL83			TIXL84			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Breakdown Voltage, $V_{(BR)}$		I_R = 100 μA, E_e = 0	80	100	120	80	100	120	V
Dark Current‡	Bulk	M = 100, E_e = 0		10	30		80	150	pA
	Surface			5	15		10	30	nA
Temperature Coefficient of Breakdown Voltage		I_R = 100 μA, E_e = 0, See Note 2		120			120		mV/°C
Photocurrent Gain at Avalanche Noise Threshold, M_T		λ = 6328 Å, See Note 3	200	>600		200	>600		
Total Capacitance, C_T		V_R = 60 V, f = 1 MHz		4	6		17	25	pF
Series Resistance		f = 0.9 GHz		25			5		Ω
Gain-Bandwidth Product†		f_{mod} = 1 GHz, λ = 6328 Å		80			80		GHz
Radiant Responsivity, R_e		λ = 6328 Å, M = 100, f_{mod}=15 GHz, $\Phi_e \leq 0.1$ mW	20	25		20	25		A/W

NOTES: 2. Temperature coefficient is determined by the formula:

$$\text{Temperature coefficient} = \frac{V_{(BR)} @ 125°C - V_{(BR)} @ -55°C}{125°C - (-55°C)}$$

3. Gain M_T is measured at the reverse voltage at which the noise deviates from the theoretical linear characteristic. See Figure 1. Radiant flux is as required to give a photocurrent of 0.1 nA rms at V_R = 20 V.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.
‡Dark current is the sum of surface current and gain M times the bulk current.
§E_e is the incident radiant power per unit area.

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TYPICAL CHARACTERISTICS

SIGNAL POWER AND NOISE POWER
vs
PHOTOCURRENT GAIN

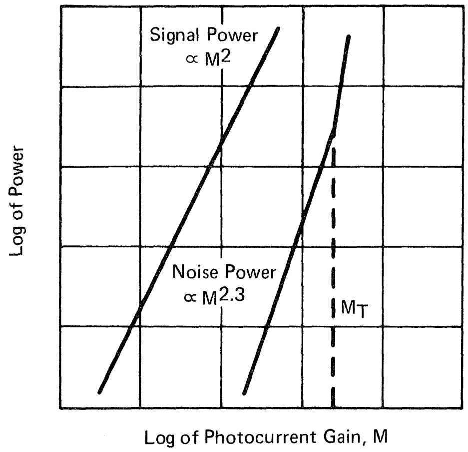

FIGURE 1

PHOTOCURRENT GAIN
vs
REVERSE VOLTAGE

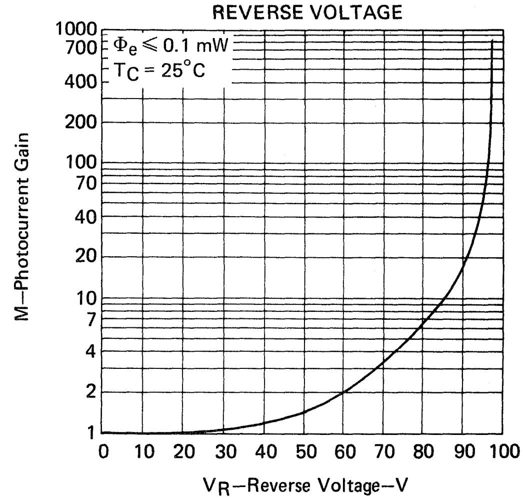

FIGURE 2

RADIANT RESPONSIVITY
vs
WAVELENGTH

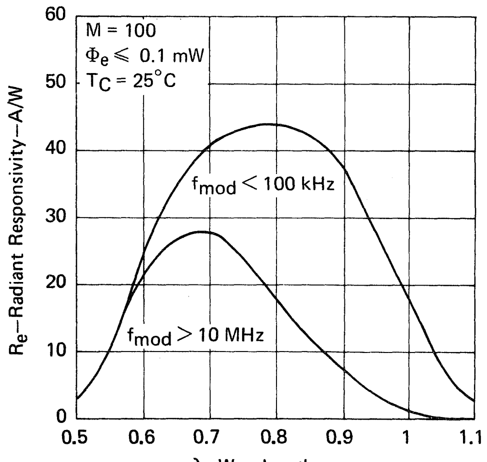

FIGURE 3

TOTAL CAPACITANCE
vs
REVERSE VOLTAGE

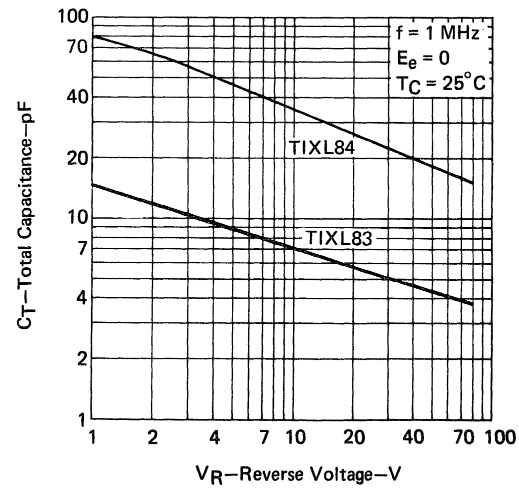

FIGURE 4

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TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

TYPES TIXL85, TIXL86
SILICON AVALANCHE PHOTODIODE/REFERENCE DIODE PAIRS

BULLETIN NO. DL-S 7412205, NOVEMBER 1974

OPTIMIZED FOR HIGH-SPEED DETECTION OF VISIBLE LIGHT

- Photodiode and Reference Diode with Matched Breakdown Characteristics
- Both Diodes Mounted on Common Ceramic but Isolated Electrically
- Choice of Active Areas of Photodiode:
  0.010-Inch Dia . . . TIXL85
  0.030-Inch Dia . . . TIXL86
- Typical Gain-Bandwidth Product† of 80 GHz

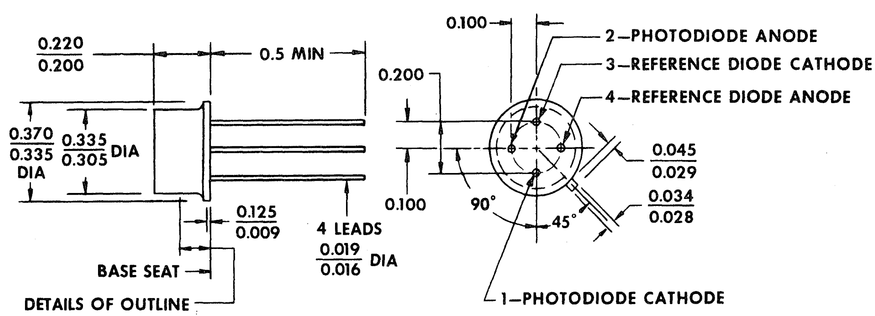
description

These diode pairs consist of an avalanche photodiode (APD) and a small reference diode that have been manufactured together to ensure close matching of both the breakdown voltages and the temperature coefficients of the two diodes. This makes it possible to build a temperature-compensating bias circuit that will hold the avalanche gain constant over wide temperature variations.

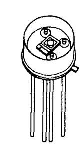
mechanical data

Each diode pair is in a hermetically sealed welded case similar to, but slightly shorter than JEDEC TO-12 with window. All TO-12 registration notes also apply to this outline. The lens is borosilicate glass. Its dimensions are: diameter, 0.305 inch; thickness, 0.060 inch; and distance from front surface of the lens to the active area, 0.075 inch.

THE REFERENCE DIODE CATHODE IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



absolute maximum ratings

Continuous Power Dissipation at (or below) 25°C Case Temperature, Each Diode (See Note 1)	50 mW
Operating Case Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	230°C

NOTE 1: Derate linearly to 125°C case temperature at the rate of 0.5 mW/°C.
†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

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TYPES TIXL85, TIXL86
SILICON AVALANCHE PHOTODIODE/REFERENCE DIODE PAIRS

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS§	TIXL85 MIN	TIXL85 TYP	TIXL85 MAX	TIXL86 MIN	TIXL86 TYP	TIXL86 MAX	UNIT
Breakdown Voltage, $V_{(BR)}$	Photodiode	I_R = 100 μA, E_e = 0	80	100	120	80	100	120	V
	Reference Diode		80	100	120	80	100	120	
Temperature Coefficient of Breakdown Voltage	Photodiode	I_R = 100 μA, E_e = 0, See Note 2	90	120	150	90	120	150	mV/°C
	Reference Diode		90	120	150	90	120	150	
Breakdown Voltage Matching, $V_{(BR)APD} - V_{(BR)REF}$		I_R = 100 μA, E_e = 0		0	±10		0	±10	V
Temperature Coefficient of Operating Voltage Matching		See Figure 5		+2	+6 −2		+2	+6 −2	mV/°C
Dark Current, I_D‡	Bulk	M = 100, E_e = 0		10	30		80	150	pA
	Surface			5	15		10	30	nA
Photocurrent Gain at Avalanche Noise Threshold, M_T		λ = 6328 Å, See Note 3	200	>600		200	>600		
Total Capacitance, C_T	Photodiode	V_R = 60 V, E_e = 0, f = 1 MHz		4	6		17	25	pF
	Reference Diode			4			4		
Series Resistance		f = 0.9 GHz, E_e = 0		25			5		Ω
Gain-Bandwidth Product†		f_{mod} = 1 GHz, λ = 6328 Å		80			80		GHz
Radiant Responsivity, R_e		λ = 6328 Å, M = 100, f_{mod} = 15 MHz, $\Phi_e \leq 0.1$ mW	20	25		20	25		A/W

NOTES: 2. Temperature coefficient is determined by the formula:

$$\text{Temperature coefficient} = \frac{V_{(BR)} @ 125^\circ C - V_{(BR)} @ -65^\circ C}{125^\circ C - (-65^\circ C)}$$

3. Gain M_T is measured at the reverse voltage at which the noise deviates from the theoretical linear characteristic. See Figure 1. Radiant flux is as required to give a photocurrent of 0.1 nA rms at V_R = 20 V.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

‡Dark Current is the sum of surface current and gain M times the bulk current.

§E_e is the incident radiant power per unit area.

TYPICAL CHARACTERISTICS

SIGNAL POWER AND NOISE POWER
vs
PHOTOCURRENT GAIN

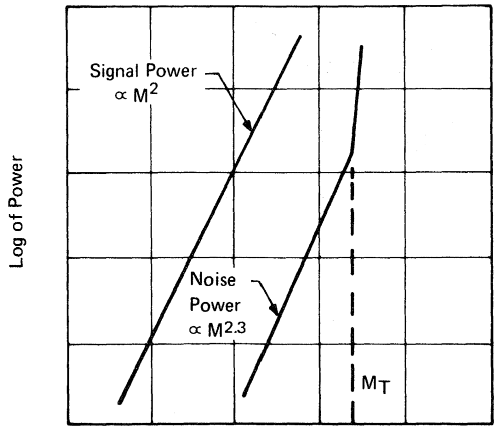

FIGURE 1

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TYPICAL CHARACTERISTICS

PHOTOCURRENT GAIN
vs
REVERSE VOLTAGE

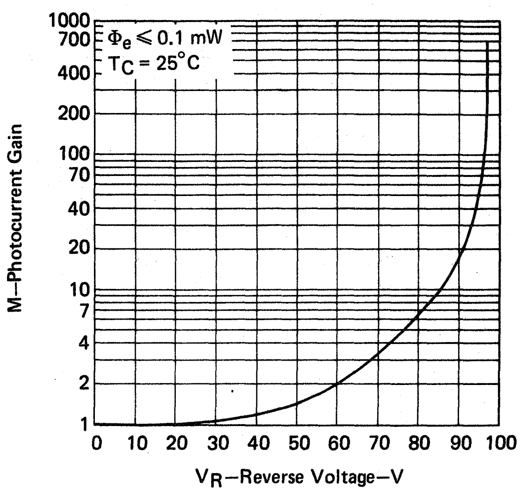


FIGURE 2

RADIANT RESPONSIVITY
vs
WAVELENGTH

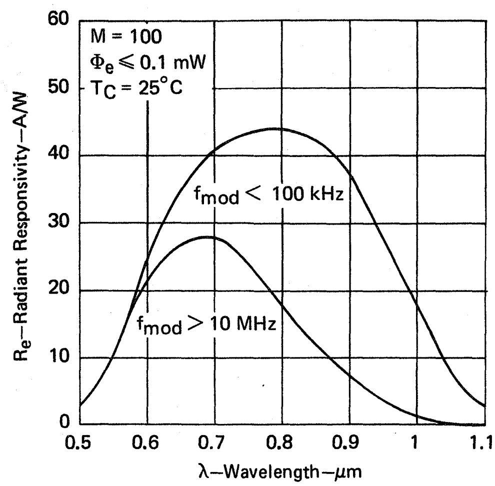


FIGURE 3

TOTAL CAPACITANCE
vs
REVERSE VOLTAGE

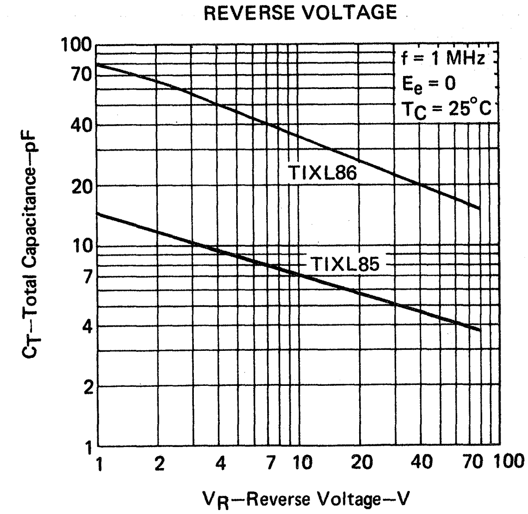


FIGURE 4

REVERSE VOLTAGE AT CONSTANT CURRENT
AND CONSTANT AVALANCHE GAIN
vs
CASE TEMPERATURE

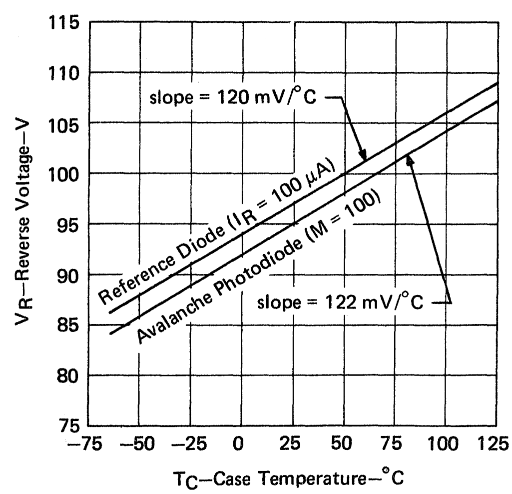


FIGURE 5

TYPICAL APPLICATION DATA

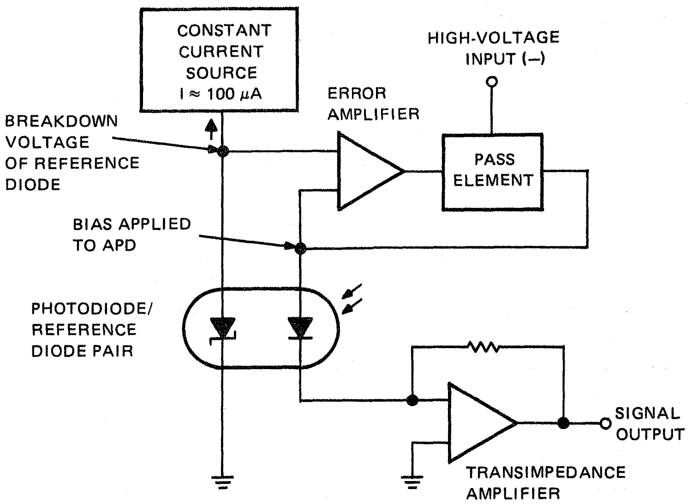
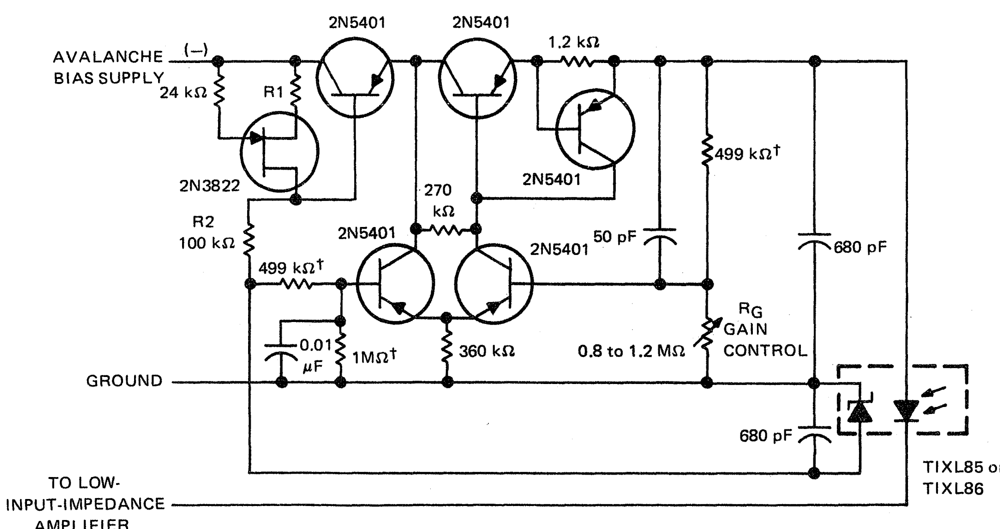


FIGURE 6—BLOCK DIAGRAM OF TEMPERATURE COMPENSATING BIAS CIRCUIT

The bias voltage applied to the APD should closely match the breakdown voltage of the reference diode (within ±10 V). In Figure 7, the bias voltage can be *increased* by *lowering* the value of the gain-control resistor. More importantly, the *change* with temperature in applied bias to the APD should closely match the *change* in breakdown voltage of the reference diode. Typically the temperature coefficient of constant avalanche gain is 2 mV/°C higher than the temperature coefficient of breakdown under conditions of constant current. The temperature coefficient of the bias circuit may be adjusted by insertion of a temperature-sensitive device in the pass element or the error amplifier.



†These resistors are T2 metal film ¼ W 1%. Other resistors are ¼ W carbon.
R1 is selected to give approximately 220 μA current through R2.
Capacitors are ceramic disc, 500 V.

FIGURE 7—SUGGESTED CIRCUIT

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PRINTED IN U.S.A. 1174

BULLETIN NO. DL-S 7412204, NOVEMBER 1974

OPTIMIZED FOR HIGH-SPEED DETECTION OF NEAR-INFRARED RADIATION

- **Photodiode and Reference Diode with Matched Breakdown Characteristics**
- **Both Diodes Mounted on Common Ceramic but Isolated Electrically**
- **Choice of Active Areas of Photodiode:**
  0.010-Inch Dia . . . TIXL87
  0.030-Inch Dia . . . TIXL88
  0.060-Inch Dia . . . TIXL89
- **Typical Gain-Bandwidth Product† of 80 GHz**

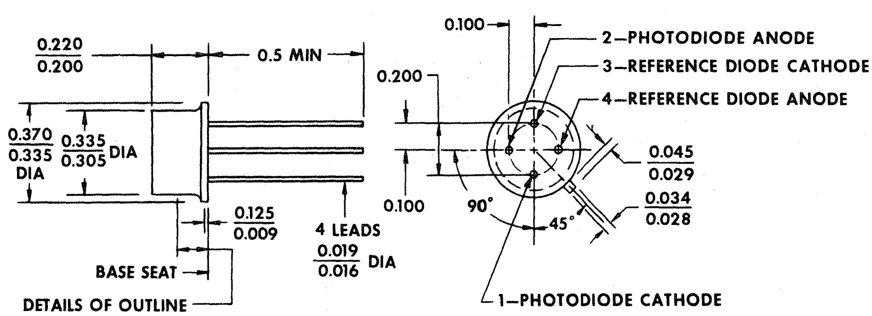
description

These diode pairs consist of an avalanche photodiode (APD) and a small reference diode that have been manufactured together to ensure close matching of both the breakdown voltages and the temperature coefficients of the two diodes. This makes it possible to build a temperature-compensating bias circuit that will hold the avalanche gain constant over wide temperature variations.

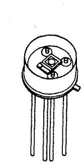
mechanical data

Each diode pair is in a hermetically sealed welded case similar to, but slightly shorter than JEDEC TO-12 with window. All TO-12 registration notes also apply to this outline. The lens is borosilicate glass. Its dimensions are: diameter, 0.305 inch; thickness, 0.060 inch; and distance from front surface of the lens to the active area, 0.075 inch.

THE REFERENCE DIODE CATHODE IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



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absolute maximum ratings

Continuous Power Dissipation at (or below) 25°C Case Temperature, Each Diode (See Note 1)	50 mW
Operating Case Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	230°C

NOTE 1: Derate linearly to 125°C case temperature at the rate of 0.5 mW/°C.
†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

TEXAS INSTRUMENTS
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electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS§	TIXL87 MIN	TIXL87 TYP	TIXL87 MAX	TIXL88 MIN	TIXL88 TYP	TIXL88 MAX	TIXL89 MIN	TIXL89 TYP	TIXL89 MAX	UNIT
Breakdown Voltage, $V_{(BR)}$	Photodiode	I_R = 100 μA, E_e = 0	155	170	185	155	170	185	155	170	185	V
	Reference Diode		155	170	185	155	170	185	155	170	185	
Temperature Coefficient of Breakdown Voltage	Photodiode	I_R = 100 μA, E_e = 0, See Note 2	170	200	230	170	200	230	170	200	230	mV/°C
	Reference Diode		170	200	230	170	200	230	170	200	230	
Breakdown Voltage Matching, $V_{(BR)APD} - V_{(BR)REF}$		I_R = 100 μA, E_e = 0		0	±10		0	±10		0	±10	V
Temperature Coefficient of Operating Voltage Matching		See Figure 5		+2	+6 −2		+2	+6 −2		+2	+6 −2	mV/°C
Dark Current, I_D‡	Bulk	M = 100, E_e = 0		5	30		60	150		140	700	pA
	Surface			0.8	10		2	20		3.5	40	nA
Photocurrent Gain at Avalanche Noise Threshold, M_T		λ = 0.9 μm, See Note 3	200	>600		200	>600		200	>600		
Total Capacitance, C_T	Photodiode	V_R = 100 V, E_e = 0, f = 1 MHz		2.5	4		9	30		30	45	pF
	Reference Diode			3			3			3		
Series Resistance		f = 0.9 GHz, E_e = 0		50			5			5		Ω
Gain-Bandwidth Product†		f_{mod} = 1 GHz, λ = 6328 Å		80			80			80		GHz
Radiant Responsivity, R_e		λ = 0.9 μm, M = 100, f_{mod}=15 MHz, $\Phi_e \leq$ 0.1 mW	15	20		15	20		15	20		A/W

NOTES: 2. Temperature coefficient is determined by the formula:

$$\text{Temperature coefficient} = \frac{V_{(BR)} @ 125°C - V_{(BR)} @ -65°C}{125°C - (-65°C)}$$

3. Gain M_T is measured at the reverse voltage at which the noise deviates from the theoretical linear characteristic. See Figure 1. Radiant flux is as required to give a photocurrent of 0.1 nA rms at V_R = 40 V.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

‡Dark Current is the sum of surface current and gain M times the bulk current.

§E_e is the incident radiant-power per unit area.

TYPICAL CHARACTERISTICS

SIGNAL POWER AND NOISE POWER
vs
PHOTOCURRENT GAIN

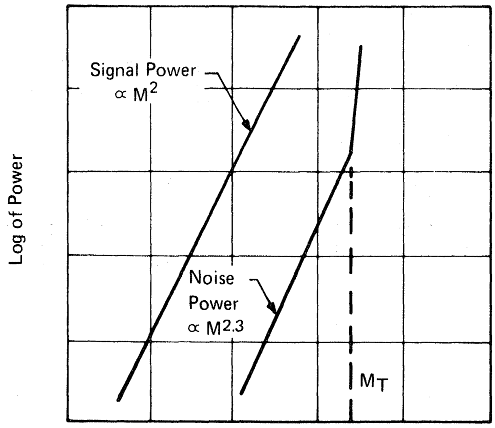

FIGURE 1

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TYPICAL CHARACTERISTICS

PHOTOCURRENT GAIN
vs
REVERSE VOLTAGE

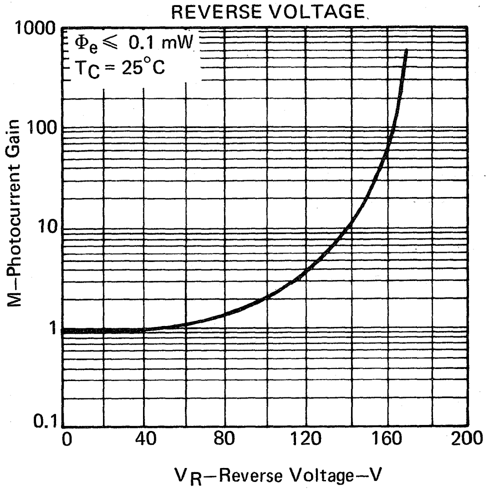

FIGURE 2

RADIANT RESPONSIVITY
vs
WAVELENGTH

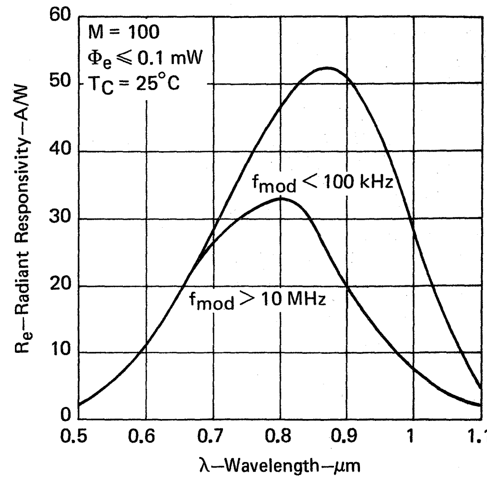

FIGURE 3

TOTAL CAPACITANCE OF PHOTODIODE
vs
REVERSE VOLTAGE

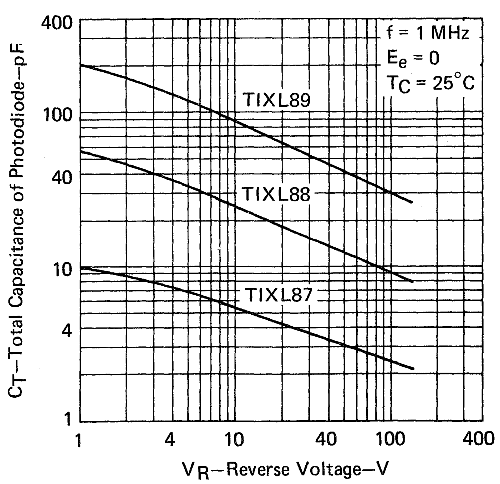

FIGURE 4

REVERSE VOLTAGE AT CONSTANT CURRENT
AND CONSTANT AVALANCHE GAIN
vs
CASE TEMPERATURE

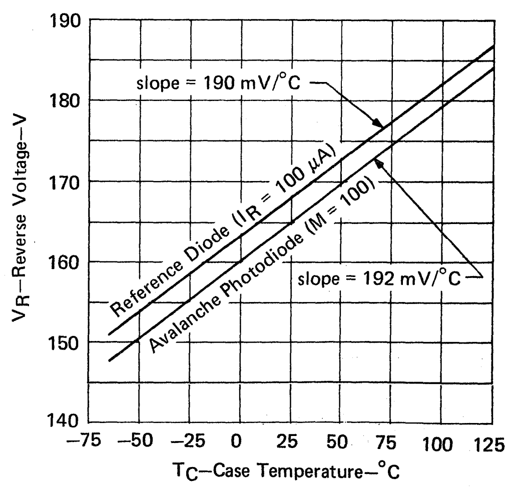

FIGURE 5

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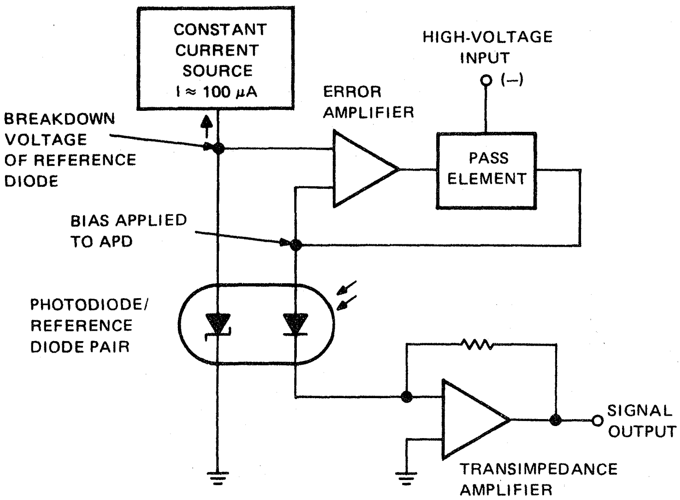
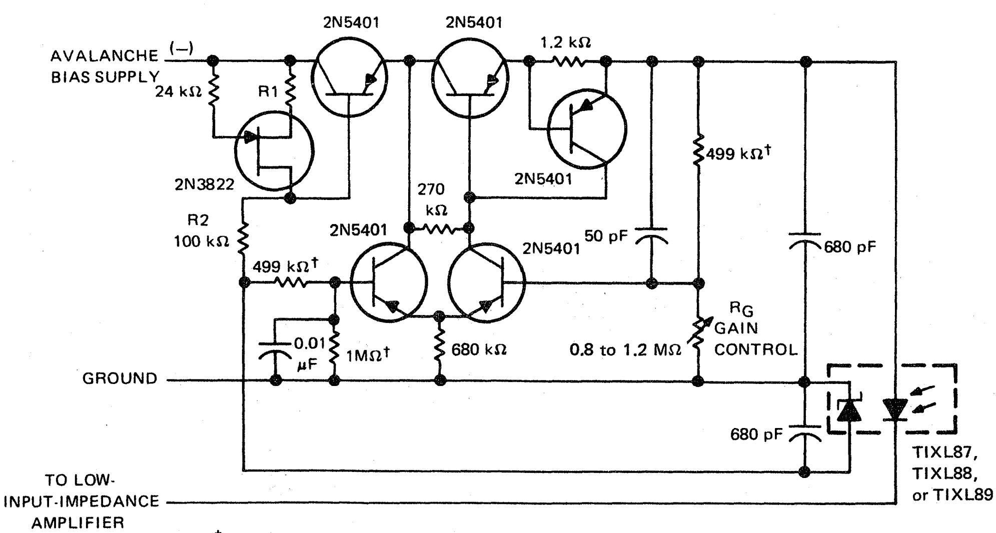
TYPICAL APPLICATION DATA



The bias voltage applied to the APD should closely match the breakdown voltage of the reference diode (within ±10 V). In Figure 7, the bias voltage can be *increased* by *lowering* the value of the gain-control resistor. More importantly, the *change* with temperature in applied bias to the APD should closely match the *change* in breakdown voltage of the reference diode. Typically the temperature coefficient of constant avalanche gain is 2 mV/°C higher than the temperature coefficient of breakdown under conditions of constant current. The temperature coefficient of the bias circuit may be adjusted by insertion of a temperature-sensitive device in the pass element or the error amplifier.

FIGURE 6—BLOCK DIAGRAM OF TEMPERATURE COMPENSATING BIAS CIRCUIT



†These resistors are T2 metal film ¼ W 1%. Other resistors are ¼ W carbon.
R1 is selected to give approximately 220 μA current through R2.
Capacitors are ceramic disc, 500 V.

FIGURE 7—SUGGESTED CIRCUIT

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PRINTED IN U.S.A. 1174

BULLETIN NO. DL-S 7612198, NOVEMBER 1974—REVISED MARCH 1976

OPTIMIZED FOR HIGH-SPEED DETECTION OF VISIBLE LIGHT

- Complete Sensitive Optical Receivers
- Choice of Active Areas . . . 0.010 Inch or 0.030 Inch Diameter
- Choice of Demodulation Bandwidths . . . 20 MHz or 50 MHz Typ
- Typical Responsivities from 1.5×10^5 to 6.1×10^5 V/W at 0.63 μm
- Typical NEP Spectral Densities from 1.2×10^{-13} to 3.4×10^{-13} W/$\sqrt{Hz}$
- Automatic Temperature Compensating Bias Circuit
- Low Power Consumption
- Low Phase Shift

ACTIVE AREA DIAMETER	NOMINAL BANDWIDTH 20 MHz	50 MHz
0.010 Inch	TIXL90	TIXL92
0.030 Inch	TIXL91	TIXL93

description

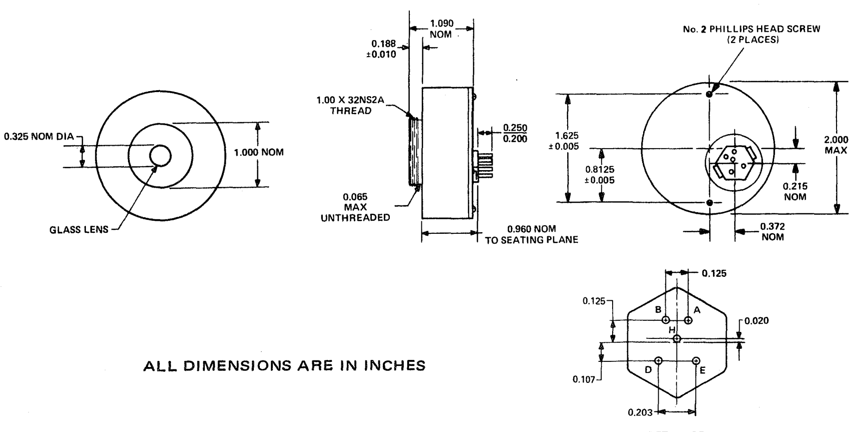
The TIXL90 through TIXL93 avalanche photodetector modules are complete optical receivers optimized for detection of low-level light signals. The high sensitivity and high speed of these devices make them ideally suited for laser range finders and optical communicators. These units contain an antireflection-coated silicon avalanche photodiode (APD), a temperature-sensing voltage reference diode, a low-noise high-frequency thick-film amplifier, and a constant-avalanche-gain regulator circuit. An internal resistor sets the avalanche gain of the module (M = 200 nominal for TIXL90 and TIXL92, M = 100 nominal for TIXL91 and TIXL93). The gain may be increased by externally connecting a resistor (usually greater than 400 kΩ) between the remote gain control (pin H) and ground (pin E).

These devices are mechanically interchangeable with the TIXL94 through TIXL97 near-infrared detectors. The wide range of choices allows the designer of an optoelectronic system to choose a detector that will best fit his complete system needs, and the interchangeability of all the different models provides for ease of detector change for different system requirements.

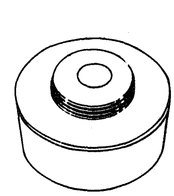
mechanical data

The modules are housed in a finished aluminum case approximately two inches in diameter and 1.3 inches in length, including connector pins. A one-inch-diameter by 0.188-inch-long threaded (32 threads/inch) portion of the case front facilitates mounting into the optical system. A flat window of borosilicate glass 0.060-inch thick and 0.300-inch in diameter is centered in the front of the housing. The avalanche photodiode is centered approximately 0.075-inch behind the front surface of the window. A five-pin plug on the rear of the module provides for the electrical connections. Total weight of the complete module is approximately 65 grams.

PIN E IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN INCHES



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TENTATIVE DATA SHEET

This document provides tentative information on a new product. Texas Instruments reserves the right to change specifications for this product in any manner without notice.

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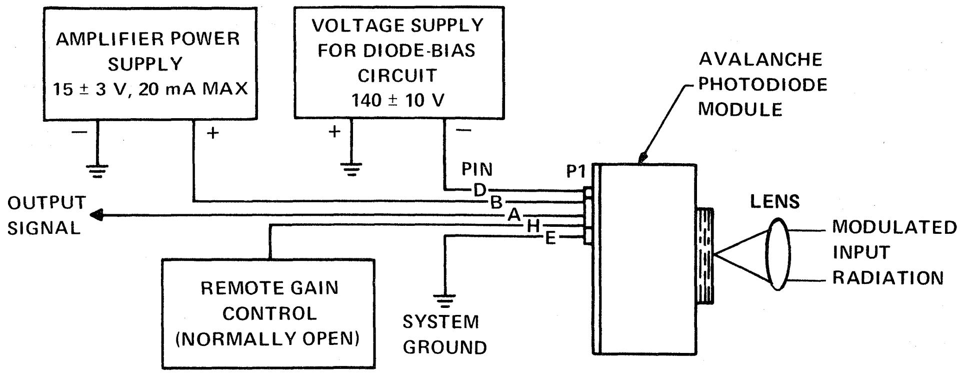
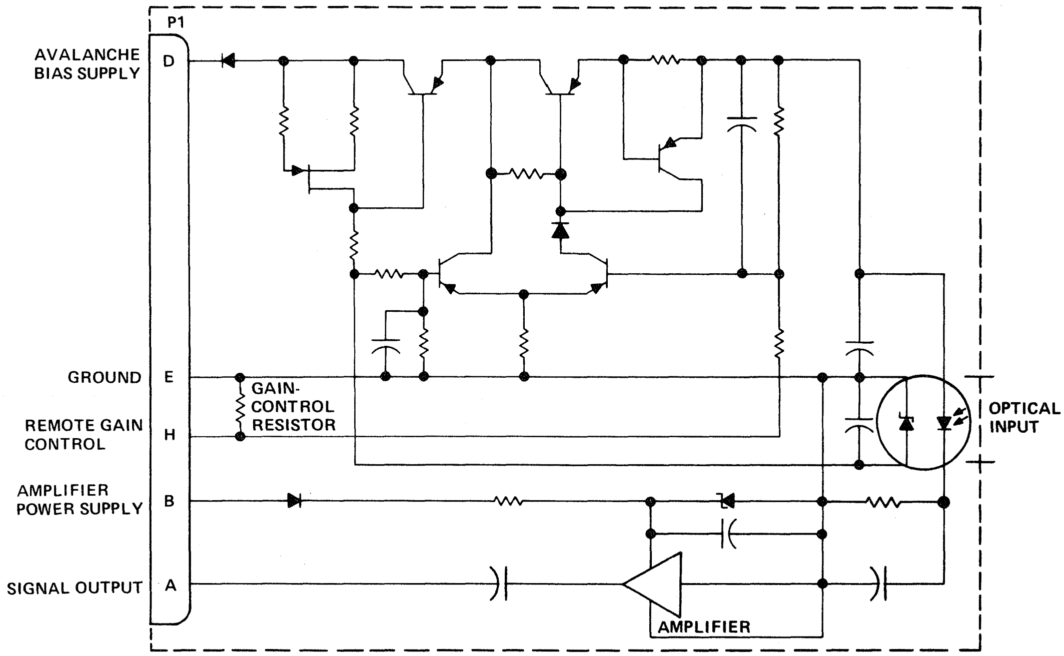
operational block diagram



schematic



absolute maximum ratings over operating case temperature range (unless otherwise noted)

Amplifier Supply Voltage, V_{AA} (See Note 1)	18 V
Avalanche Bias Supply Voltage, V_{DD} (See Note 1)	−150 V
Operating Case Temperature Range	−40°C to 60°C
Storage Temperature Range	−55°C to 125°C

NOTE 1: All voltage values are with respect to pin E (GND) unless otherwise noted.

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electrical connections to plug, P1 (see schematic)

PIN	DESCRIPTION	POWER REQUIRED
A	Signal Output	
B	Amplifier Supply	15 ± 3 V, 20 mA max
D	Avalanche Bias Supply	−140 ± 10 V, 1 mA max
E	Ground	
H	Remote Gain Control†	

†Normally open. A resistor connected between pins E and H raises the avalanche gain of the APD.

electrical characteristics at 25°C case temperature (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	TIXL90			TIXL91			TIXL92			TIXL93			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
R_e	Radiant Responsivity	Φ_e = 30 nW, λ = 0.63 μm, f_{mod} = 15 MHz, R_L = 50 Ω	0.4	0.61		0.2	0.3		0.2	0.3		0.1	0.15		mV/nW
M	Avalanche Gain			200			100			200			100		
ΔM/M	APD Gain Variation over Rated Operating Temperature Range (See Note 2)			±5	±15		±5	±15		±5	±15		±5	±15	%
V_n	Broadband Noise Voltage	Φ_e = 0, R_L = 50 Ω		410	615		460	690		400	600		450	675	μV
P_n	Noise Equivalent Power Spectral Density (See Note 3)			0.12	0.2		0.27	0.4		0.15	0.25		0.34	0.5	pW/$\sqrt{Hz}$
B_m	Module Demodulation Bandwidth‡	See Note 4	15	20		15	20		40	50		40	50		MHz
V_o	Maximum RMS Output Voltage	R_L = 50 Ω	100			100			100			100			mV
z_o	Amplifier Output Impedance	f = 20 kHz		4	15		4	15		2	15		2	15	Ω

NOTES: 2. Gain variation, ΔM/M, is determined by the formula: $\pm\Delta M/M = \frac{M @ 60°C - M @ -40°C}{M @ 60°C + M @ -40°C} \times 100\%$.

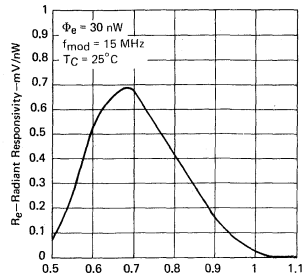
3. $P_n = \frac{V_n}{R_e \sqrt{\pi B_m/2}}$, where V_n = broadband rms noise voltage and equivalent noise bandwidth $\Delta f = \pi B_m/2$.

4. Since the gain-bandwidth product of the APD is approximately 100 GHz, the module demodulation bandwidth can be determined from electrical bandwidth measurements performed on the module amplifier. The input signal level to the amplifier is 5 μA.

‡For these modules, the lower end of the bandwidth is 3.5 kHz.

TYPICAL CHARACTERISTICS

TIXL90
RADIANT RESPONSIVITY
vs
WAVELENGTH



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BULLETIN NO. DL-S 7612197, NOVEMBER 1974–REVISED MARCH 1976

OPTIMIZED FOR HIGH-SPEED DETECTION OF NEAR-INFRARED RADIATION

- **Complete Sensitive Optical Receivers**
- **Choice of Active Areas . . . 0.010 Inch or 0.030 Inch Diameter**
- **Choice of Demodulation Bandwidths . . . 20 MHz or 50 MHz Typ**
- **Typical Responsivities from 1.1 X 10^5 to 4.7 X 10^5 V/W at 0.9 μm**
- **Typical NEP Spectral Densities from 1.5 X 10^{-13} to 4.3 X 10^{-13} W/$\sqrt{\text{Hz}}$**
- **Automatic Temperature Compensating Bias Circuit**
- **Low Power Consumption**
- **Low Phase Shift**

ACTIVE AREA DIAMETER	NOMINAL BANDWIDTH 20 MHz	50 MHz
0.010 Inch	TIXL94	TIXL96
0.030 Inch	TIXL95	TIXL97

description

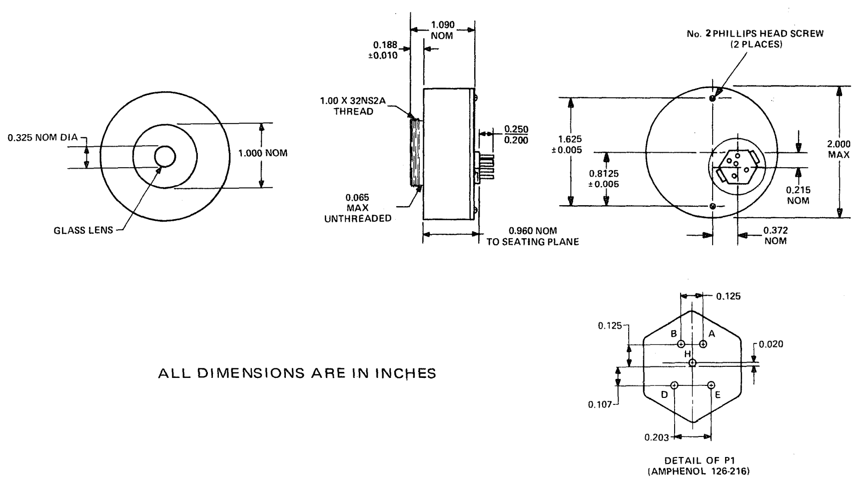
The TIXL94 through TIXL97 avalanche photodetector modules are complete optical receivers optimized for detection of low-level near-infrared signals. The high sensitivity and high speed of these devices make them ideally suited for laser range finders and optical communicators. These units contain an antireflection-coated silicon avalanche photodiode (APD), a temperature-sensing voltage reference diode, a low-noise high-frequency thick-film amplifier, and a constant-avalanche-gain regulator circuit. An internal resistor sets the avalanche gain of the module (M = 200 nominal for TIXL94 and TIXL96, M = 100 nominal for TIXL95 and TIXL97). The gain may be increased by externally connecting a resistor (usually greater than 400 kΩ) between the remote gain control (pin H) and ground (pin E).

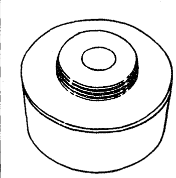
These devices are mechanically interchangeable with the TIXL90 through TIXL93 visible light detectors. The wide range of choices allows the designer of an optoelectronic system to choose a detector that will best fit his complete system needs, and the interchangeability of all the different models provides for ease of detector change for different system requirements.

mechanical data

The modules are housed in a finished aluminum case approximately two inches in diameter and 1.3 inches in length, including connector pins. A one-inch-diameter by 0.188-inch-long threaded (32 threads/inch) portion of the case front facilitates mounting into the optical system. A flat window of borosilicate glass 0.060-inch thick and 0.300-inch in diameter is centered in the front of the housing. The avalanche photodiode is centered approximately 0.075-inch behind the front surface of the window. A five-pin plug on the rear of the module provides for the electrical connections. Total weight of the complete module is approximately 65 grams.

PIN E IS IN ELECTRICAL CONTACT WITH THE CASE





TENTATIVE DATA SHEET

This document provides tentative information on a new product. Texas Instruments reserves the right to change specifications for this product in any manner without notice.

TEXAS INSTRUMENTS
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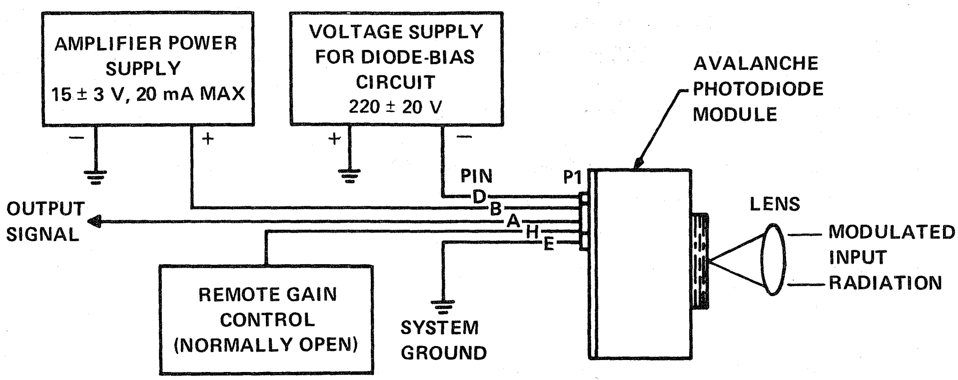
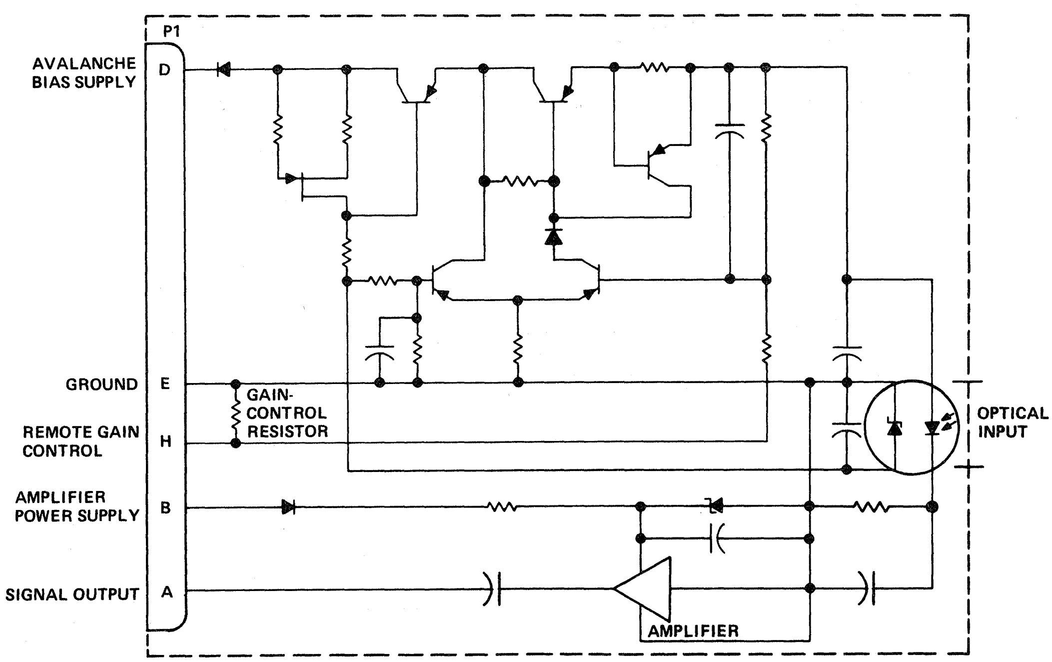
operational block diagram



schematic



absolute maximum ratings over operating case temperature range (unless otherwise noted)

Amplifier Supply Voltage, V_{AA} (See Note 1)	18 V
Avalanche Bias Supply Voltage, V_{DD} (See Note 1)	−240 V
Operating Case Temperature Range	−40°C to 60°C
Storage Temperature Range	−55°C to 125°C

NOTE 1: All voltage values are with respect to pin E (GND) unless otherwise noted.

electrical connections to plug, P1 (see schematic)

PIN	DESCRIPTION	POWER REQUIRED
A	Signal Output	
B	Amplifier Supply	15 ± 3 V, 20 mA max
D	Avalanche Bias Supply	−220 ± 20 V, 1 mA max
E	Ground	
H	Remote Gain Control†	

†Normally open. A resistor connected between pins E and H raises the avalanche gain of the APD.

electrical characteristics at 25°C case temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TIXL94			TIXL95			TIXL96			TIXL97			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
R_e	Radiant Responsivity	Φ_e = 50 nW, λ = 0.9 µm, f_{mod} = 15 MHz, R_L = 50 Ω	0.3	0.47		0.16	0.24		0.15	0.23		0.07	0.11		mV/nW
M	Avalanche Gain			200			100			200			100		
ΔM/M	APD Gain Variation over Rated Operating Temperature Range (See Note 2)			±5	±15		±5	±15		±5	±15		±5	±15	%
V_n	Broadband Noise Voltage	Φ_e = 0, R_L = 50 Ω		400	600		385	580		400	600		415	625	µV
P_n	Noise Equivalent Power Spectral Density (See Note 3)			0.15	0.25		0.29	0.5		0.20	0.3		0.43	0.65	pW/$\sqrt{Hz}$
B_m	Module Demodulation Bandwidth‡	See Note 4	15	20		15	20		40	50		40	50		MHz
V_o	Maximum RMS Output Voltage	R_L = 50 Ω	100			100			100			100			mV
z_o	Amplifier Output Impedance	f = 20 kHz		4	15		4	15		2	15		2	15	Ω

NOTES: 2. Gain variation, ΔM/M, is determined by the formula: $\pm\Delta M/M = \frac{M @ 60°C - M @ -40°C}{M @ 60°C + M @ -40°C} \times 100\%$.

3. $P_n = \frac{V_n}{R_e\sqrt{\pi B_m/2}}$, where V_n = broadband rms noise voltage and equivalent noise bandwidth $\Delta f = \pi B_m/2$.

4. Since the gain-bandwidth product of the APD is approximately 100 GHz, the module demodulation bandwidth can be determined from electrical bandwidth measurements performed on the module amplifier. The input signal level to the amplifier is 5 µA.

‡For these modules, the lower end of the bandwidth is 3.5 kHz.

TYPICAL CHARACTERISTICS

TIXL94
RADIANT RESPONSIVITY
vs
WAVELENGTH

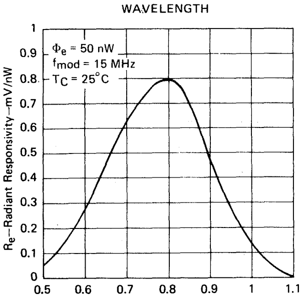


FIGURE 1

TIXL96
RADIANT RESPONSIVITY
vs
MODULATION FREQUENCY

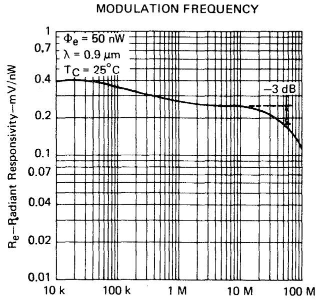


FIGURE 2

NOTE:
The increased response at low frequencies (<3 MHz) is due to hole-electron pairs that are created outside of the depletion region and move at slow diffusion velocity to the depletion region where they are swept out at high velocity. This effect only occurs at relatively long wavelength (>0.8 µm) and even then, the majority(≈2/3) of the carriers are created in the high-field depletion region.

HIGH-RESISTIVITY SILICON PHOTODIODE

BULLETIN NO. DL-S 7412192, NOVEMBER 1974

- Wide Spectral Bandwidth
- Typical Radiant Responsivity . . . 0.5 A/W at 0.9 μm
  0.27 A/W at 0.56 μm
- Diameter of Photodiode Active Area . . . 0.040 inch
- Low Capacitance . . . 2 pF Typ at V_R = 12 V
- Dark Current . . . 2 nA Typ at V_R = 25 V

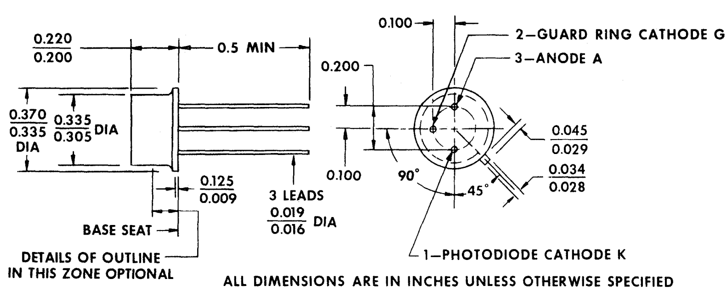
description

The TIXL98 is a high-performance silicon photodiode designed to operate in a reverse-bias mode. High-resistivity silicon is used to provide high 0.9-μm responsivity and low capacitance at low voltage. The device has a guard-ring structure to minimize active-area dark current and to provide excellent low-noise characteristics.

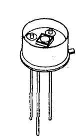
mechanical data

The device is in a hermetically sealed welded case similar to, but slightly shorter than, JEDEC TO-5 with window. All TO-5 registration notes also apply to this outline. The lens is borosilicate glass. Its nominal dimensions are: diameter, 0.305 inch; thickness, 0.050 inch; and distance from front surface of the lens to the active area, 0.100 inch.

THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE



ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED



absolute maximum ratings

Continuous Power Dissipation at (or below) 25°C Case Temperature (See Note 1)	100 mW
Operating Case Temperature Range	−65°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	300°C

electrical characteristics at 25°C case temperature

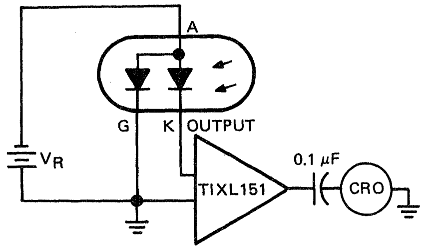
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(BR)}$	Breakdown Voltage	I_R = 100 μA, E_e = 0, See Notes 2 and 3	50	100		V
I_D	Dark Current, Photodiode	V_R = 25 V, E_e = 0, See Notes 2 and 4		2	10	nA
C_T	Total Capacitance	V_R = 12 V, f = 1 MHz, E_e = 0		2	3	pF
		V_R = 25 V, f = 1 MHz, E_e = 0		1.5	2	
R_e	Radiant Responsivity	V_R = 12 V, λ = 0.56 μm	0.18	0.27		A/W
		V_R = 12 V, λ = 0.9 μm	0.4	0.5		

NOTES:
1. Derate linearly to 125°C case temperature at the rate of 1 mW/°C.
2. Irradiance (E_e) is the radiant power per unit area incident on a surface.
3. Breakdown voltage is measured with the photodiode and guard-ring cathodes connected together.
4. Dark current of the photodiode is measured in a circuit similar to the switching circuit (Figure 1). A current meter (with a full-scale voltage drop of 1 mV maximum) replaces the TIXL151 and measures the dark current of the photodiode cathode with the guard-ring cathode at ground.

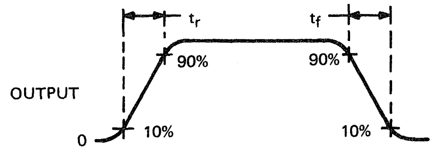
switching characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS	TYPICAL	UNIT
t_r	Rise Time	$I_L = 10\ \mu A$, $V_R = 25$ V, See Figure 1	45	ns
t_f	Fall Time		45	ns

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORM

NOTES: a. Input irradiance is supplied by a pulsed GaAs infrared emitter, $t_w \leq 200$ ns, $t_r \leq 5$ ns, $\lambda = 0.9\ \mu m$. Incident irradiation is adjusted for $I_L = 10\ \mu A$.

b. The output waveform is monitored on a oscilloscope with the following characteristics: $t_r \leq 2.5$ ns, $R_{in} = 50\ \Omega$.

FIGURE 1–SWITCHING TIMES

TYPICAL CHARACTERISTICS

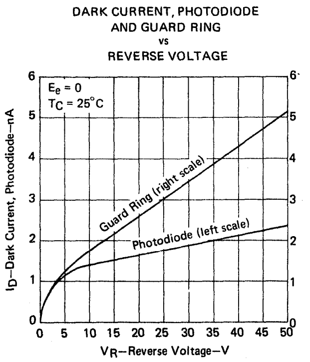


FIGURE 2

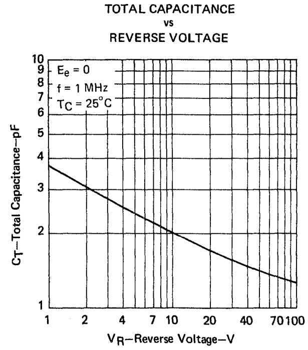


FIGURE 3

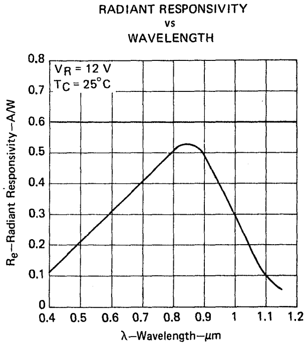


FIGURE 4

BULLETIN NO. DL-S 7412193, NOVEMBER 1974

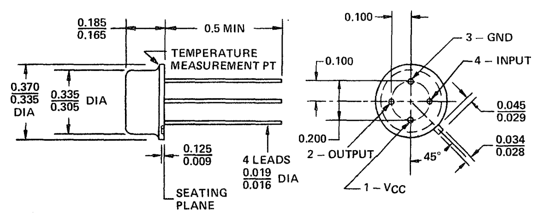
OPTOELECTRONIC INTERFACE CIRCUITS FOR IMPROVED SENSITIVITY IN APPLICATIONS SUCH AS LASER RANGEFINDERS AND OPTICAL COMMUNICATIONS

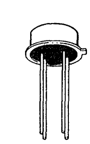
- **Designed for Current Sources such as Photodiodes and Photomultiplier Tubes**
- **Transimpedance Circuit Provides Output Voltage Linearly Proportional to Input Current**
- **Typical Frequency Responses from DC to 100 MHz, 50 MHz, and 20 MHz**
- **Typical Equivalent Input Noise Current Spectral Densities of 7.5 pA/$\sqrt{Hz}$, 4.5 pA/$\sqrt{Hz}$, and 3 pA/$\sqrt{Hz}$**
- **Low Input Impedance for Tolerance of High Source Capacitance**
- **Low Output Impedance for Loads as Small as 50 Ohms‡**
- **Single Supply of 4 to 6 Volts**

mechanical data

The device is in a hermetically sealed welded case similar to but shorter than JEDEC TO-12. All TO-12 registration notes also apply to this outline.

LEAD 3 IS IN ELECTRICAL CONTACT WITH THE CASE





All dimensions are in inches unless otherwise specified

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Supply voltage V_{CC}		8 V
Continuous Input Current Range:	TIXL150	−5 mA to 2 mA
	TIXL151	−1.2 mA to 2 mA
	TIXL152	−0.5 mA to 2 mA
External Load Conductance		20 mmho‡
Operating Free-Air Temperature Range		−55°C to 125°C
Storage Temperature Range		−65°C to 150°C
Lead Temperature 1/16 Inch from Case for 10 Seconds		240°C

†Equivalent input noise current is defined as broadband rms output voltage divided by z_f and by the square root of noise bandwidth. The noise bandwidth is $\pi/2$ times the signal bandwidth measured between the frequencies at which response is down 3 dB with a high-frequency rolloff of 6 dB/octave.

‡Capacitive coupling is required for load resistances smaller than 1000 ohms to minimize disturbance of the amplifier bias.

TENTATIVE DATA SHEET

This document provides tentative information on a new product. Texas Instruments reserves the right to change specifications for this product in any manner without notice.

TEXAS INSTRUMENTS INCORPORATED
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electrical characteristics at 25°C free-air temperature, V_{CC} = 5.8 V

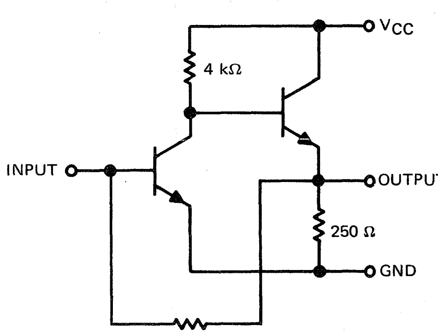
PARAMETER		TEST CONDITIONS§	TIXL150			TIXL151			TIXL152			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
I_n	Equivalent Input Noise Current†	R_L = 50 Ω, See Note 1		8.5	10		4.5	7		3	5.5	pA/√Hz
z_f	Forward Transfer Impedance	R_L = 50 Ω, f = 20 kHz	0.8	1.0		2.8	4		8	12		kΩ
z_i	Input Impedance	R_L = 50 Ω, f = 20 kHz		35	70		100	140		300	500	Ω
z_o	Output Impedance	I_{in} = 0, f = 20 kHz		0.5	5		2	10		4	12	Ω
V_o	Maximum RMS Output Voltage	R_L = 50 Ω, f = 20 kHz	100			100			100			mV
B	Bandwidth (−3 dB)	R_L = 50 Ω	90	100		40	50		12	20		MHz
V_{IQ}	Quiescent Input Voltage	Input open		0.7			0.7			0.7		V
V_{OQ}	Quiescent Output Voltage	Input open		0.8			0.8			0.8		V
I_{CC}	Supply Current	Input open		4	6		4	6		4	7	mA

†Equivalent input noise current is defined as broadband rms output voltage divided by z_f and by the square root of noise bandwidth. The noise bandwidth is π/2 times the signal bandwidth measured between the frequencies at which response is down 3 dB with a high-frequency roll-off of 6 dB/octave.

§Output coupling capacitance = 1 μF, V_{CC} bypass capacitance = 0.01 μF.

NOTE 1: Equivalent input noise current is determined using a post amplifier with response down 3 dB at 10 kHz and 150 MHz. Therefore, the overall signal bandwidth is equal to the bandwidth of the device under test.

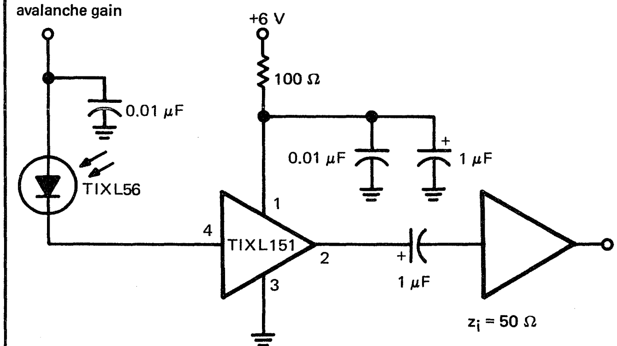
schematic



VALUE APPROXIMATELY EQUAL TO z_f

Resistor values shown are nominal

typical application



TYPICAL PERFORMANCE FOR M = 100, λ = 0.9 μm

R_e = 2.3 X 10^5 V/W

NEP = 2 X 10^{-13} W/√Hz

f_{lower} = 3 kHz

f_{upper} = 50 MHz

BULLETIN NO. DL-S 7412125, JULY 1974—REVISED NOVEMBER 1974

DESIGNED FOR FIBER-OPTIC APPLICATIONS

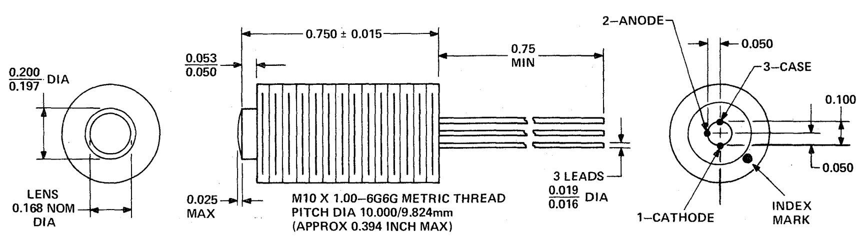
- Direct Self-Aligning Connection to T-19H Optical-Waveguide Termination
- Isolated Panel-Mounting Case
- Optimized for Near-Infrared Sources
- Useful from Audio to Microwave Frequencies
- Minimum Photocurrent Gain of 200
- Typical Gain-Bandwidth Product† of 80 GHz
- Typical System Noise Equivalent Power of 2×10^{-13} W/$\sqrt{Hz}$ over 30-MHz Bandwidth

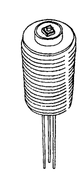
description

The TIXL451 is a high-speed photodiode intended for use with optical-waveguide fiber bundles. This device is designed to operate in the avalanche region to provide gain for excellent low-noise performance over wide bandwidths. The TIXL451 is electrically similar to TIXL59.

mechanical data

The device is in an anodized-aluminum threaded case filled with clear epoxy. This package mates directly with a CORNING™ T-19H termination. The geometry is such that when the device is attached to the self-aligning termination, the cone of light (8° half angle) emitted from the fiber-optic bundle will fall on the active area of the detector (4.5×10^{-3} cm^2, diameter of 0.030 inch). The active area surface is nominally 0.020 inch below the front surface of the epoxy. the index of refraction of which is 1.49. This package can be panel mounted with a set of hex nuts supplied with the device.





Dimensions without tolerance designate true position. Leads having maximum diameter (0.019") measured in gaging plane 0.054" +0.001" −0.000" below the seating plane of the device shall be within 0.007" of their true positions.

ALL DIMENSIONS ARE IN INCHES (UNLESS OTHERWISE NOTED)

absolute maximum ratings

Continuous Power Dissipation at (or below) 25°C Case Temperature (See Note 1)	100 mW
Operating Case Temperature Range	−40°C to 60°C
Storage Temperature Range	−40°C to 80°C
Lead Temperature 1/16 Inch from Case for 10 Seconds	230°C

NOTE 1: Derate linearly to 65 mW at 60°C case temperature at the rate of 1 mW/°C.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

1

TEXAS INSTRUMENTS
INCORPORATED
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electrical characteristics at 25°C case temperature

PARAMETER		TEST CONDITIONS§	MIN	TYP	MAX	UNIT
Breakdown Voltage, $V_{(BR)}$		$I_R = 100\ \mu A$, $E_e = 0$	155	170	185	V
Dark Current‡	Bulk	M = 100, $E_e = 0$		60	150	pA
	Surface			2	20	nA
Temperature Coefficient of Breakdown Voltage		$I_R = 100\mu A$, $E_e = 0$, See Note 2		200		mV/°C
Photocurrent Gain at Avalanche Noise Threshold, M_T		$\lambda = 0.9\ \mu m$, See Note 3	200	>600		
Total Capacitance, C_T		$V_R = 100$ V, f = 1 MHz		8.5	12	pF
Series Resistance		f = 0.9 GHz		5		Ω
Gain-Bandwidth Product†		$f_{mod} = 1$ GHz, $\lambda = 6328$ Å		80		GHz
Radiant Responsivity, R_e		$\lambda = 0.9\mu m$, M=100, $f_{mod} = 15$ MHz	15	20		A/W

NOTES: 2. Temperature coefficient is determined by the formula:

$$\text{Temperature coefficient} = \frac{V_{(BR)} @ 125°C - V_{(BR)} @ -55°C}{125\ °C - (-55°C)}$$

3. Gain M_T is measured at the reverse voltage at which the noise deviates from the theoretical linear characteristic. See Fgiure 1. Radiant flux is as required to give a photocurrent of 0.1 nA rms at $V_R = 40$ V.

†Gain-bandwidth product is the gain times the frequency of measurement when the diode is biased for maximum obtainable gain.

‡Dark current is the sum of surface current and gain M times the bulk current.

§E_e is the incident radiant power per unit area

TYPICAL CHARACTERISTICS

SIGNAL POWER AND NOISE POWER vs PHOTOCURRENT GAIN

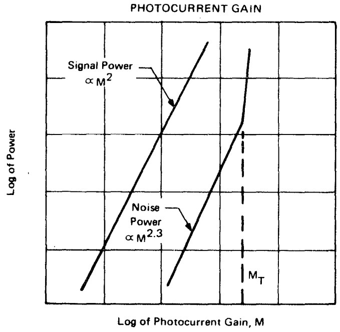

FIGURE 1

PHOTOCURRENT GAIN vs REVERSE VOLTAGE

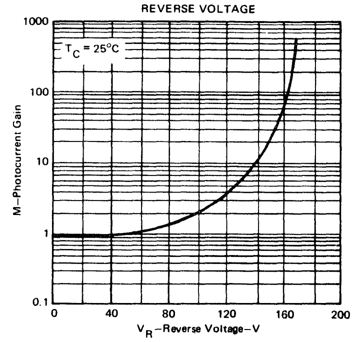

FIGURE 2

RADIANT RESPONSIVITY vs WAVELENGTH

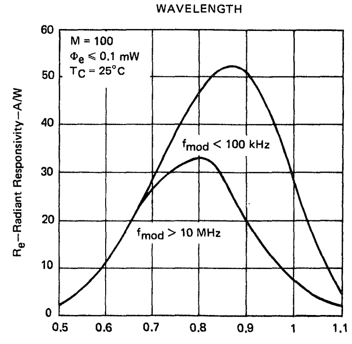

FIGURE 3

10

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BULLETIN NO. DL-S 7412169, SEPTEMBER 1974

COMPLETE OPTICAL WAVEGUIDE RECEIVER

- **Direct Self-Aligning Coupling to T-19H Optical Waveguide Termination**
- **Bandwidth Extends from DC to 50 MHz Typical**
- **Designed for 0.6-μm to 1.06-μm Wavelengths**
- **Typical Responsivity with 0.9-μm Radiation Is 200 mV/μW**
- **Typical System Noise Equivalent Power with 0.9-μm Radiation Is 2×10^{-13} W/$\sqrt{Hz}$**
- **Small Cylindrical Shape, 2-Inch Diameter by 1.5-Inch Length**
- **Automatically Regulated Avalanche-Gain Bias Circuit**
- **Low Power Consumption**

description

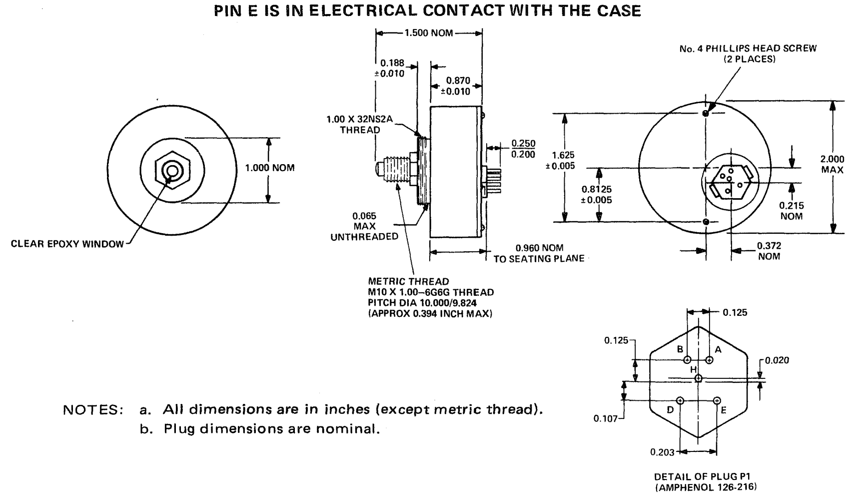
The TIXL452 is a complete avalanche photodetector module designed for use with optical-waveguide fiber bundles. The unit contains a silicon avalanche photodiode (APD), a temperature-sensing voltage reference diode, a low-noise, high-frequency, thin-film amplifier, and a regulated avalanche-gain bias circuit. The avalanche gain is internally fixed at 125. The high sensitivity of these devices makes them ideally suited for use in fiber-optic communications or data links employing LED transmitters.

mechanical data

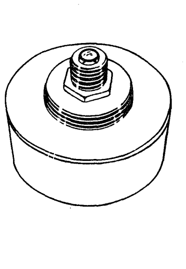
The TIXL452 consists of a TIXL59/TIXL451 photodector chip and TIXL451 waveguide-termination package matched with a reference diode and an electronics section. A finished aluminum housing protects the electronics and provides threads for mounting to the system. The extended chip package is threaded to mate with the CORNING™ T-19H optical-waveguide termination. The geometry is such that when the unit is attached to the self-aligning termination, the cone of light (8° half angle) emitted from the fiber-optic bundle will fall on the active area (4.5×10^{-3} cm^2, diameter = 0.030 inch). The APD is contained within the clear epoxy window, with its active-area surface nominally 0.020 inch below the outer surface of the epoxy. The index of refraction of the window is 1.49.

The five-pin plug on the rear of the module provides for the electrical connections. Total weight of the complete module is approximately 65 grams.

PIN E IS IN ELECTRICAL CONTACT WITH THE CASE



NOTES: a. All dimensions are in inches (except metric thread).
b. Plug dimensions are nominal.



absolute maximum ratings over operating case temperature range (unless otherwise noted)

Amplifier Supply Voltage, V_{AA} (See Note 1) . . . . 9.5 V
Diode-Bias-Circuit Supply Voltage, V_{DD} (See Note 1) . . . . −230 V
Operating Case Temperature Range . . . . −40°C to 60°C
Storage Temperature Range . . . . −40°C to 80°C

NOTE 1: All voltage values are with respect to pin E (GND).

electrical connections to plug P1 (see schematic)

PIN	DESCRIPTION	POWER REQUIRED
A	Signal Output	
B	Amplifier Supply	8.5 ± 0.5 V, 20 mA max
D	Diode-Bias-Circuit Supply	MIN† to −230 V, 2 mA max
E	Ground	
H	No Connection	

†The minimum required value of diode-bias-circuit supply voltage is supplied with other data for each individual module.

electrical characteristics at 25°C case temperature, R_L = 50 Ω, M = 125 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
Module Responsivity, R_m	f = 3 kHz, λ = 0.9 μm	75		mV/μW
	f = 3 kHz, λ = 1.06 μm	20		
Noise Equivalent Power, NEP (See Note 2)	λ = 0.9 μm		0.5	$pW/\sqrt{Hz}$
	λ = 1.06 μm		1.5	
APD Gain Variation over Operating Temperature Range, ΔM/M	T_C = −40°C to 60°C		±15%	
Module Demodulation Bandwidth (3-dB), B_m §		40		MHz
Amplifier Output Impedance, z_o	f = 20 kHz		10	Ω

NOTE 2: NEP $= \frac{V_n}{R_m\sqrt{\Delta f}}$, where V_n = broadband output noise voltage and $\Delta f = B_m\ \pi/2$.
§For this module, the bandwidth extends from dc to the upper cutoff frequency.

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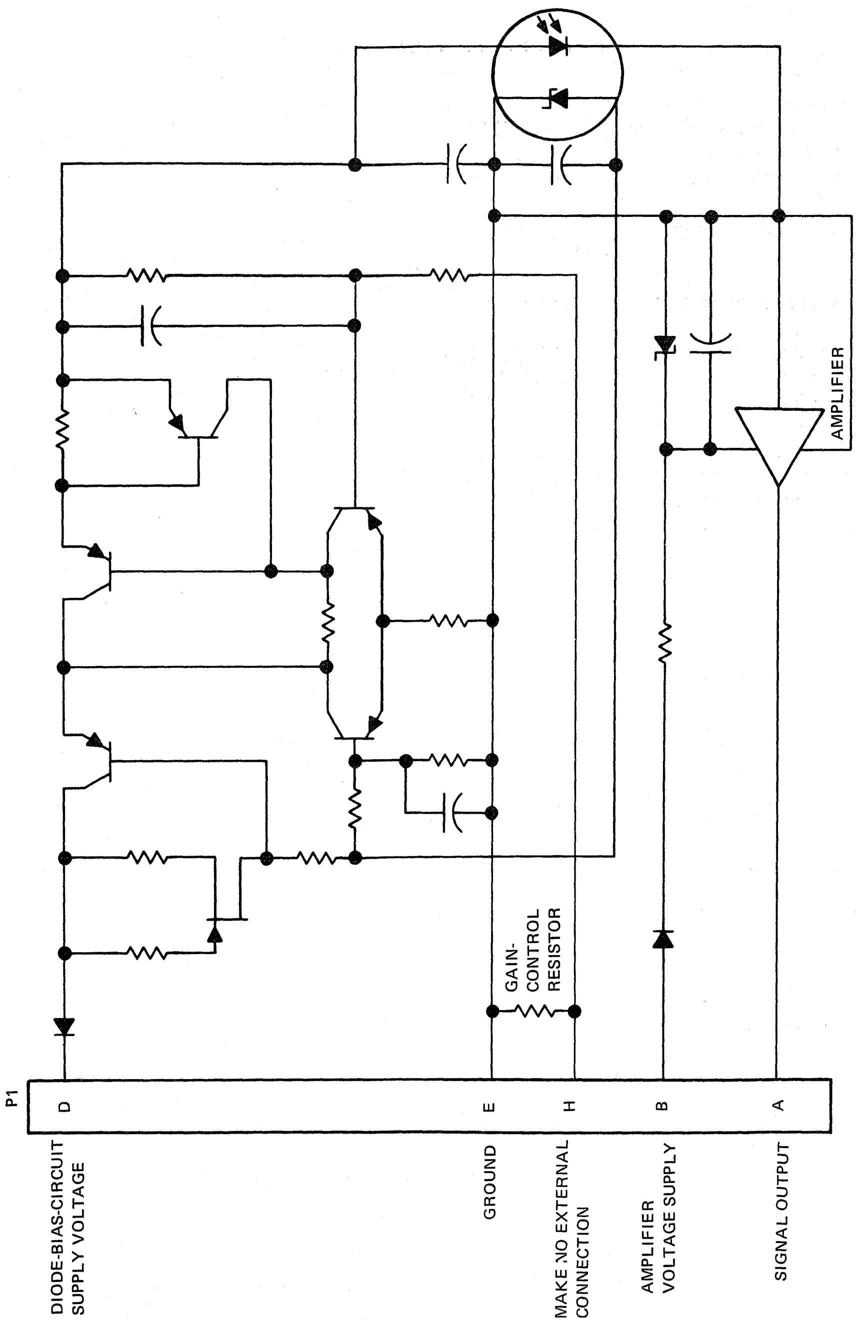
module schematic



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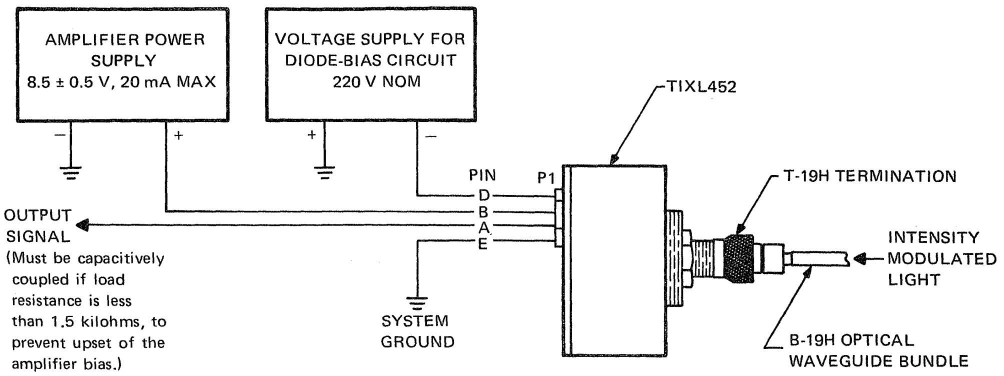
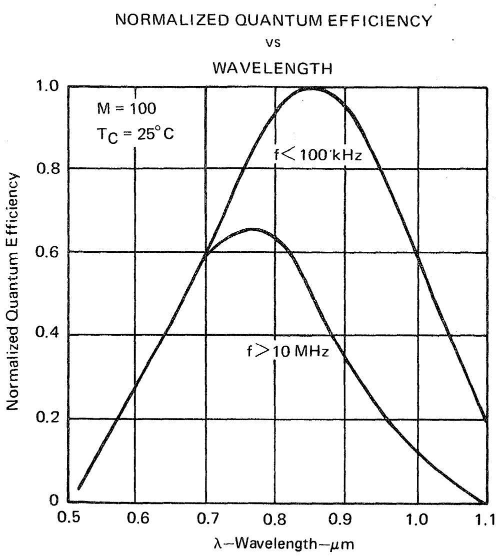
operational block diagram



TYPICAL CHARACTERISTICS



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PRINTED IN U.S.A. 974

TYPE TIXL471
P-N GALLIUM ARSENIDE INFRARED-EMITTING DIODE

BULLETIN NO. DL-S 7412144, JULY 1974

DESIGNED FOR FIBER-OPTIC APPLICATIONS

- **Direct Self-Aligning Connection to T-19H Optical Waveguide Termination**
- **Typical Coupling Efficiency of 5 x 10^{-3} with CORNING™ B-19 Optical Waveguide**
- **Fast, Linear Response to 30 MHz**
- **Dome-Shaped 0.018-Inch-Diameter Chip**
- **Peak Emission at 0.91 μm**

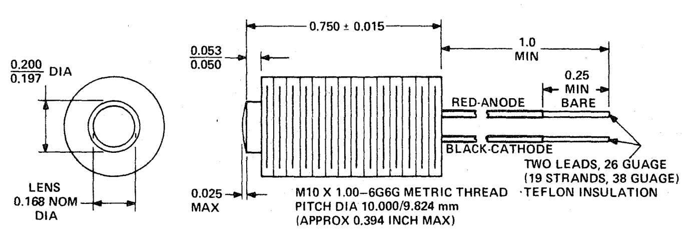
description

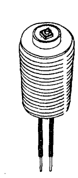
The TIXL471 is a high-speed infrared-emitting diode intended for use with optical-waveguide fiber bundles in prototype applications. Typical radiant power coupled into these bundles is 5 μW which is sufficient signal for compatible silicon avalanche photodiodes such as the TIXL451.

mechanical data

The gallium arsenide dome-shaped chip is mounted in the threaded connector and is encapsulated in epoxy to provide a flat, clear window at the top of the case. This package mates directly with a CORNING T-19H termination. The package can be panel mounted with the set of hex nuts supplied with the device.

THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE





ALL DIMENSIONS IN INCHES (EXCEPT METRIC THREAD)

absolute maximum ratings

Reverse Voltage at 25°C Case Temperature	2 V
Peak Forward Current at (or below) 25°C Case Temperature (See Note 1)	300 mA
Continuous Forward Current at (or below) 25°C Case Temperature (See Note 2)	150 mA
Storage Temperature Range	−65°C to 100°C
Lead Temperature 1/16 Inch from Case for 5 Seconds	230°C

NOTES: 1. This value applies for $t_w \leq 100\ \mu s$, duty cycle ≤ 50%.
2. Derate linearly to 100°C case temperature at the rate of 2 mA/°C.

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TENTATIVE DATA SHEET
This document provides tentative information on a new product. Texas Instruments reserves the right to change specifications for this product in any manner without notice.

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operating characteristics at 25°C case temperature

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output	I_F = 50 mA	0.5	1		mW
λ_p	Wavelength at Peak Emission			0.91		μm
$\Delta\lambda$	Spectral Bandwidth			230		Å
θ_{HI}	Half-Intensity Beam Angle			130°		
V_F	Static Forward Voltage			1.35	1.8	V
t_r	Radiant Pulse Rise Time†	I_{FM} = 50 mA, t_w = 100 ns, f = 100 kHz		15		ns

†Radiant pulse rise time is the time required for a change in radiant power output from 10% to 90% of its peak value for a step change in current.

TYPICAL CHARACTERISTICS

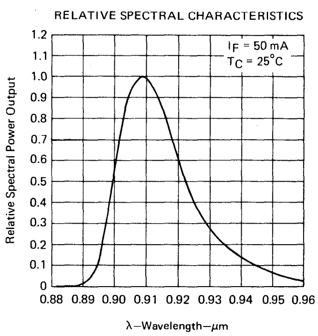

FIGURE 1

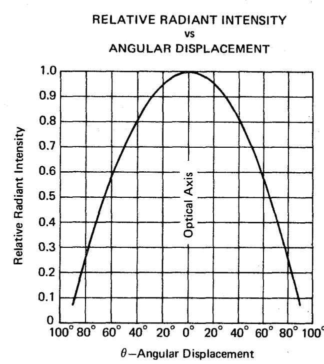

FIGURE 2

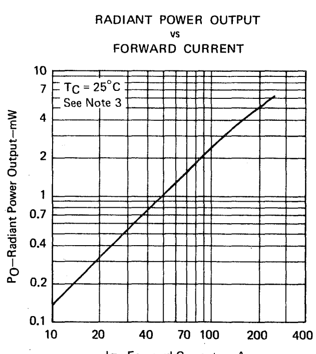

FIGURE 3

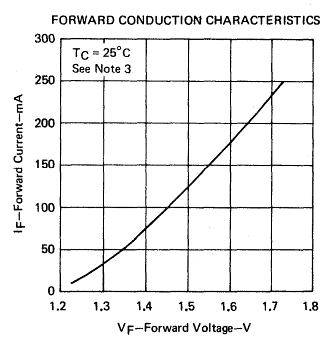

FIGURE 4

NOTE 3: These parameters must be measured using pulse techniques. t_w = 100 μs, duty cycle ⩽ 50%.

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DESIGNED FOR DIGITAL DATA TRANSMISSION

- **Direct Self-Aligning Coupling to T-19H Optical Waveguide Termination**
- **Dome-Shaped 0.018-Inch-Diameter Gallium Arsenide Source for Improved Coupling to Low-Loss Optical Waveguides**
- **Peak Emission at 0.91 μm for Optimum Match to Silicon Detectors such as the TIXL452 Avalanche Photodetector Module**
- **Typical Rise Time of 15 ns**
- **TTL Positive-Logic Input, Active-Low Enable** • **Single Power Supply**

description

The TIXL472 is a complete optical-waveguide transmitter module designed for use with optical-waveguide fiber bundles. The unit contains a gallium-arsenide, high-speed, infrared-emitting diode (IRED), and a high-speed, high-efficiency integrated current driver. Two TTL-compatible inputs are provided. The IRED will be on only when the signal input, A, is high while the enable input, $\overline{E}$, is low. If the value of the external current-setting resistor is less than 50 ohms and the signal input is continuously high or open, provision should be made for the enable input to also be high or open to avoid excess IRED power dissipation.

FUNCTION TABLE

INPUT $\overline{E}$	INPUT A	IRED
OPEN	X	OFF
H	X	OFF
L	L	OFF
L	H	ON

H = high level, L = low level, X = irrelevant

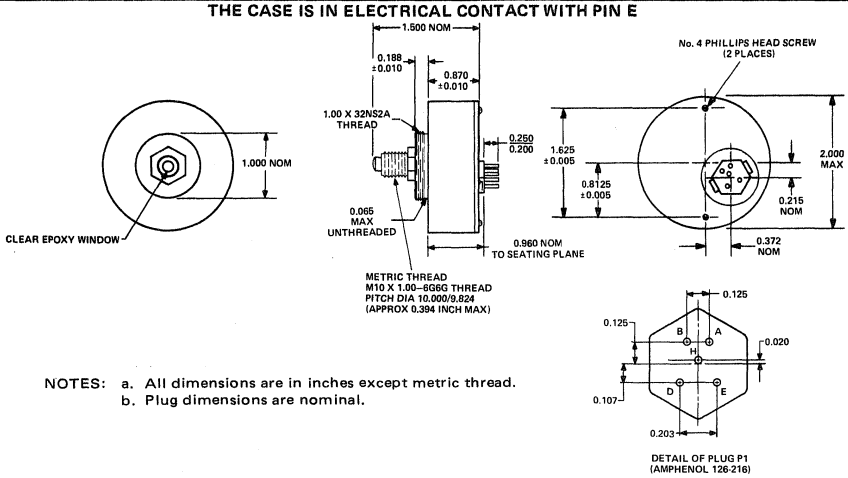
The IRED is dome-shaped to couple more light into the 8° acceptance half-angle of a low-loss optical waveguide. Coupling efficiency into standard 30° acceptance half-angle fiber-optic bundles is excellent. This module mates directly with a CORNING™ T-19H termination. A complete digital optical waveguide link can be formed using this module, an optical waveguide bundle, and a TIXL452 avalanche photodetector module.

mechanical data

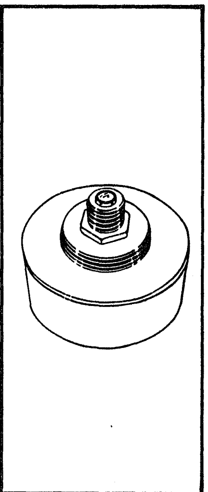
The TIXL472 consists of a TIXL471 gallium arsenide IRED matched with a TTL-compatible electronic driver circuit and is packaged in a finished aluminum housing. The housing, measuring 2 inches by 1.5 inches maximum, protects the electronics section and provides threads for mounting to the system. The dome-shaped IRED chip is mounted in the extended, threaded portion of the module and is encapsulated in epoxy to provide a flat, clear window. The index of refraction of the window is 1.49. The active area surface is nominally 0.020 inch below the front surface of the epoxy.

The five-pin plug on the rear of the module provides for the electrical connections. Total weight of the complete module is approximately 50 grams.

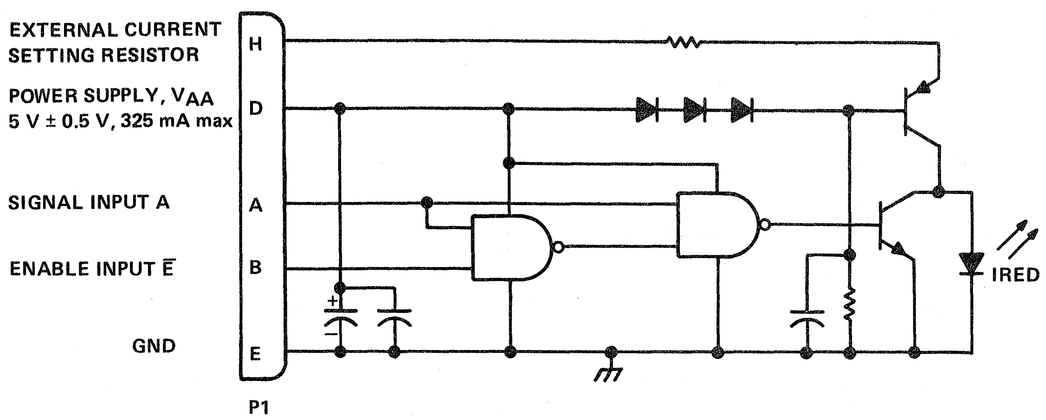
THE CASE IS IN ELECTRICAL CONTACT WITH PIN E



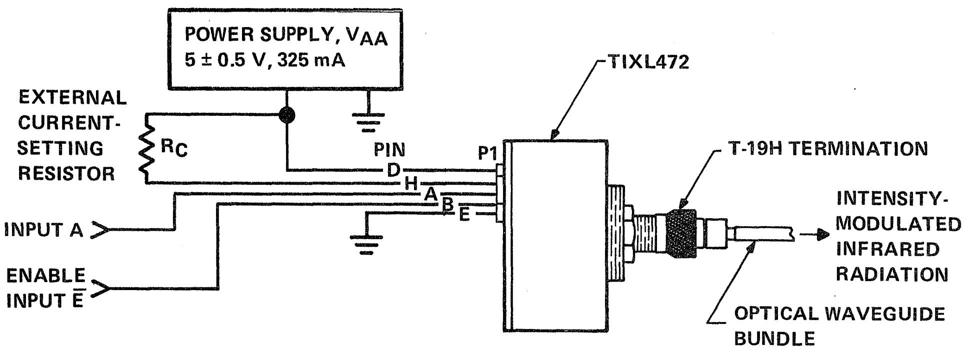
NOTES: a. All dimensions are in inches except metric thread.
b. Plug dimensions are nominal.



module schematic



operational block diagram



The wiring to the external current-setting resistor, R_C, should be as short as possible and twisted or preferably shielded to avoid radiation of r-f interference to surrounding equipment. R_C should be nonínductive (carbon composition is suitable). For power dissipation calculations the continuous current through R_C can be taken from Figure 4.

absolute maximum ratings at 25°C case temperature (unless otherwise noted)

Power Supply Voltage, V_{AA} (See Note 1) . . . . 5.5 V
Input Voltage . . . . 5.5 V
Range of Values for External Current-Setting Resistor, R_C, for Continuous Operation . . . . 50 Ω to ∞
Duty Cycle for $R_C = 0$ 50%
Operating Case Temperature Range . . . . −40°C to 60°C
Storage Temperature Range . . . . −40°C to 80°C

NOTE 1: All voltage values are with respect to pin E (GND).

operating characteristics at 25°C case temperature, $V_{AA} = 5$ V

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
P_O	Radiant Power Output		$R_C = 34\ \Omega$ ($I_F \approx 50$ mA)	0.5	1		mW
	Radiant Power Coupled into Waveguide B-19H			2.5	5		μW
λ_p	Wavelength at Peak Emission				0.91		μm
$\Delta\lambda$	Spectral Bandwidth				230		Å
θ_{HI}	Half-Intensity Beam Angle				130°		
t_r	Radiant Pulse Rise Time†		$I_{FM} = 100$ mA, $t_w = 100$ ns, f = 100 kHz		15	20	ns
V_{IH}	High-Level Input Voltage			2			V
V_{IL}	Low-Level Input Voltage					0.8	V
I_I	Input Current at Maximum Input Voltage	Input A	$V_I = 5.5$ V			2	mA
		Enable $\bar{E}$				1	
I_{IH}	High-Level Input Current	Input A	$V_I = 2.4$ V			80	μA
		Enable $\bar{E}$				40	
I_{IL}	Low-Level Input Current	Input A	$V_I = 0.4$ V			−3.2	mA
		Enable $\bar{E}$				−1.6	

†Radiant pulse rise time is the time required for a change in radiant power output from 10% to 90% of its peak value for a step change in current. The pulse source should have a 50-Ω output impedance.

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TYPICAL CHARACTERISTICS

RELATIVE SPECTRAL CHARACTERISTICS

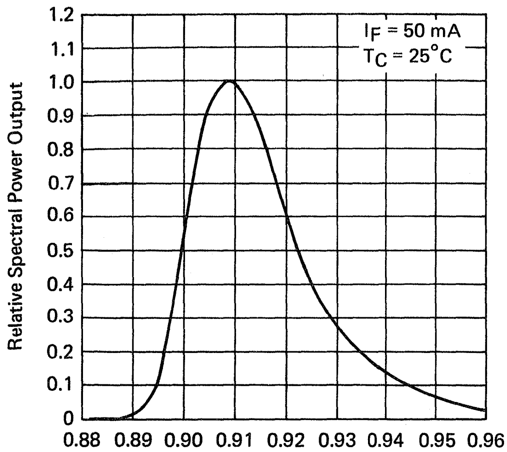

FIGURE 1

RELATIVE RADIANT INTENSITY
vs
ANGULAR DISPLACEMENT

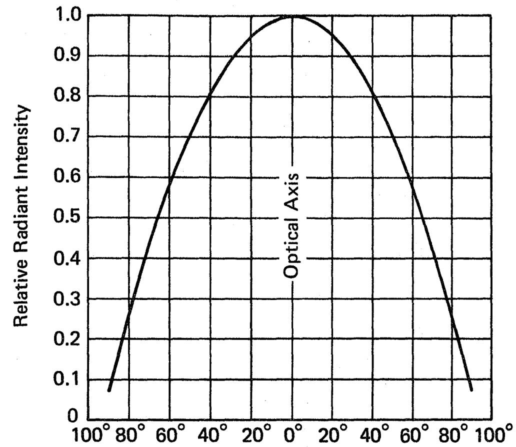

FIGURE 2

RADIANT POWER OUTPUT
vs
FORWARD CURRENT OF IRED

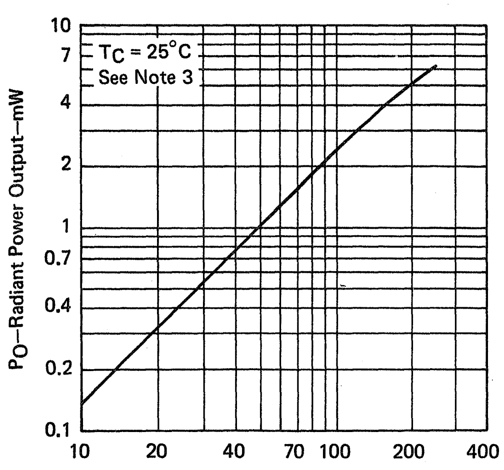

FIGURE 3

FORWARD CURRENT OF IRED
vs
VALUE OF EXTERNAL CURRENT SETTING RESISTOR

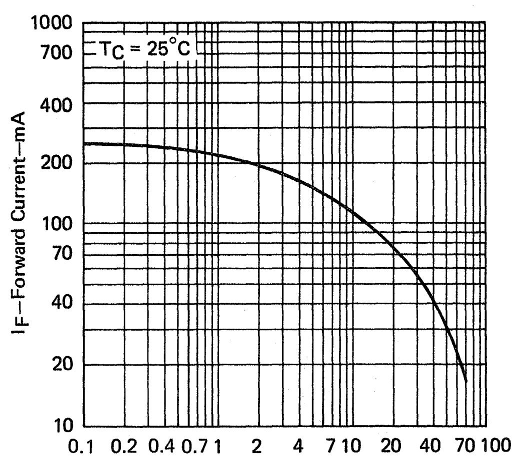

FIGURE 4

NOTE 3: These parameters must be measured using pulse techniques. t_w = 100 μs, duty cycle ≤ 50%.

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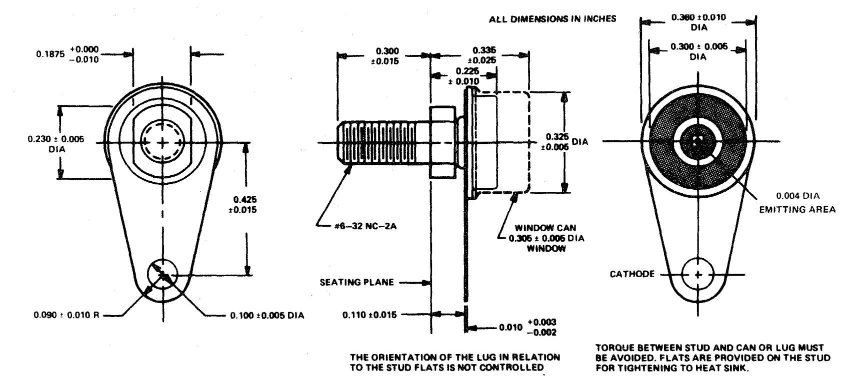
BULLETIN NO. DL-S 7612383, MARCH 1976

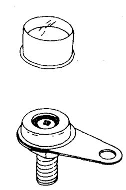
DESIGNED FOR FIBER-OPTIC APPLICATIONS

- Small-Area, High-Radiance, High-Speed Emitter Designed for Coupling to Single Optical Fibers
- Circular Emitting Area . . . 4 Mils Diameter
- Etched-Well Device Design for High Radiance
- High Speed . . . 15 ns Typical Risetime
- Stud Mounting for Convenient Heat Sinking

mechanical data

The cathode is in electrical contact with the case and adjacent solder lug. The anode is in electrical contact with the stud, which is insulated from the case by a glass-to-metal seal. Soldered connections should not be made directly to the stud because of the low-thermal-resistance path between the stud and emitting element. The window can is not sealed to the header.





absolute maximum ratings

Reverse Voltage at 25°C Case Temperature . . . . 2 V
Continuous Forward Current at (or below) 25°C Case Temperature (See Note 1) . . . . 100 mA
Storage Temperature Range . . . . −55°C to 100°C
Solder Lug Temperature for 10 Seconds . . . . 240°C

operating characteristics at 25°C case temperature (without window can in place)

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_e	Radiant Intensity (See Notes 2 and 3)	TIXL474	I_F = 100 mA	70	100		μW/sr
		TIXL474A		120	160		
λ_p	Wavelength at Peak Emission				903		nm
$\Delta\lambda$	Spectral Bandwidth				28		nm
V_F	Static Forward Voltage				1.7	2	V
t_r	Radiant Pulse Rise Time (See Note 4)				15		ns

NOTES: 1. Derate linearly to 25 mA at 100°C case temperature at the rate of 1.0 mA/°C.
2. Radiant intensity is determined by measuring radiant power incident on a 0.5-inch-diameter detector positioned 1.0 inch from the emitter. The detector subtends a solid angle of 0.19 sr.
3. Radiant power coupled into a single step-index optical fiber with a core diameter greater than the emitting diameter is approximately equal to pi times the radiant intensity times the square of the fiber numerical aperture.
4. Radiant pulse risetime is the time required for a change in radiant intensity from 10% to 90% of its peak value for a step change in current.

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EFFICIENT HIGH-POWER GaAs EMITTERS

Larry D. Major and Ronald D. Grotti

The Gallium Arsenide (GaAs) hemispherical emitter is a solution-grown infrared emitting diode (IRED). It offers the highest optical power available in spontaneous infrared emitters, together with increased light quanta efficiency. The outputs of the TIXL12-TIXL16 series of IRED's range from 20 mW to 200 mW at their respective forward bias currents.

These infrared emitters are capable of meeting applicable Mil-Std tests, and find applications in optical communications.

This report presents basic information necessary to fully utilize these high optical power output and high efficiency infrared emitters.

Topics discussed include:

Theory of Operation

Device Performance

- Series Resistance
- Forward Voltage
- Optical Power
- Spectral Distribution
- Radiant Intensity
- Thermal Impedance
- Frequency Response

Package Configuration and Design

Typical GaAs Emitter Circuits

THEORY OF OPERATION

The GaAs spontaneous infrared emitter is essentially a solution-grown P-N junction isolated by mesa formation in the shape of 36 mil and 72 mil diameter hemispheres.

Its theory of operation is similar to silicon and germanium emitters. In each case the P-type and the N-type regions are formed in a single crystal.

When the P-N junction is forward biased, electrons from the N region are injected into the P region and radiant quanta (photons) are generated through recombination. This radiant energy is emitted in the near-infrared region.

The hemispheric dome structure provides a substantial increase in radiant source quanta efficiency from that of flat geometry sources.

The radiant source quanta efficiency (η_S) is defined by the equation

$$\eta_S = \frac{q N_S}{I_F} \qquad (1)$$

where

N_S = the external photon rate
q = the electronic charge
I_F = the forward current

It is clear from equation (1) that any increase in N_s would mean an increase in efficiency.

When the ratio of the junction radius to the dome radius is equal to the sine of the critical angle, that is, when

$$\sin\theta_c = \frac{r_j}{R_o} \qquad (2)$$

where

r_j = the junction radius,
R_o = the dome radius, and
θ_c = critical angle,

all the radiation reaching the surface of the hemisphere will make an angle less than θ_c with the normal to the surface.

Under these conditions total internal reflection is eliminated. The external photon rate (N_s) is maximized, increasing efficiency of the device.

DEVICE PERFORMANCE

SERIES RESISTANCE

The voltage-current characteristic, (Figures 1, 2, and 3,) for an IRED can be approximated by the following equation,

$$I = I_O \left(e^{\frac{qv}{nKT}} - 1 \right) \qquad (3)$$

where

I = forward current
I_O = reverse saturation current
q = electron charge
v = applied voltage
K = Boltzmann constant
T = temperature

At normal operating conditions, I≫Io. Therefore differentiating equation (3) we get

$$\frac{dV}{dI} = \frac{nKT}{qI} \equiv r \qquad (4)$$

where

r = series resistance

From equation (4) it is obvious that r is a function of I. However over the normal operating region r can be approximated and considered constant. The value of r can be measured from the V-I characteristic. Table I shows

Table I

SERIES RESISTANCE (T = 25°C)			
Device Type	Min r (Ω)	Typical r (Ω)	Max r (Ω)
TIXL 12, 13	0.75	0.90	1.05
TIXL 14, 15, 16	0.13	0.17	0.21

values obtained from the V-I characteristics for the TIXL12-TIXL16 series.

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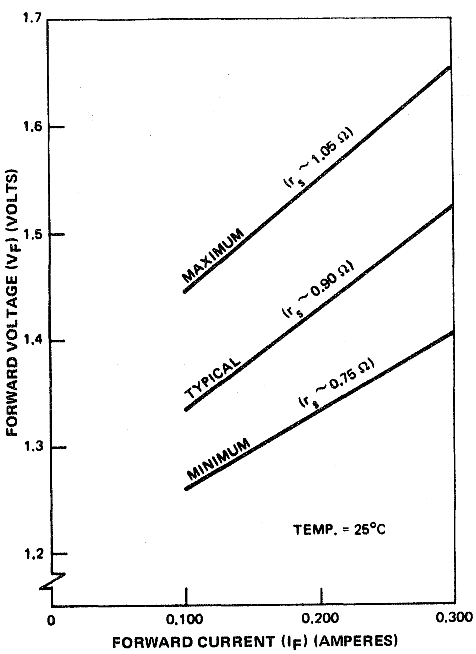

FIGURE 1. Forward Voltage-Forward Current Characteristics For TIXL12 and TIXL13

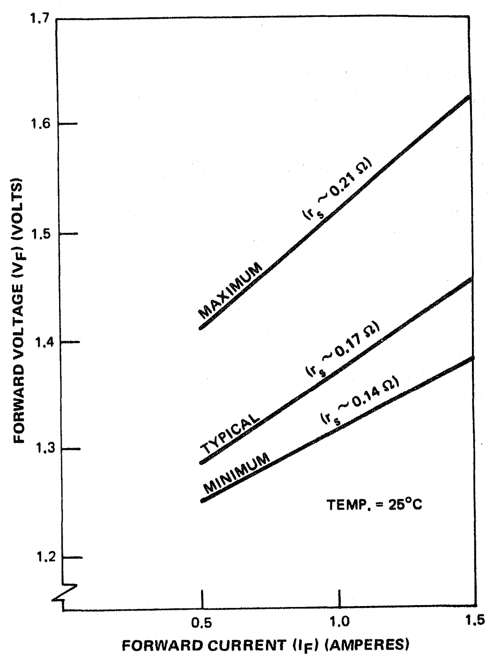

FIGURE 2. Forward Voltage-Forward Current Characteristics For TIXL14 and TIXL15

FORWARD VOLTAGE

The GaAs IRED's exhibit forward voltage-temperature dependence values lower than accepted values for silicon.

The value of dV/dT is a function of current. Average values of dV/dT may be calculated from the forward voltage-temperature curves, Figures 4, 5, and 6.

Average values of dV/dT obtained from Figures 4, 5, and 6 are shown in Table II.

Table II

Device Type	ΔV/ΔT
TIXL 12, 13	−1.5 mV/°C
TIXL 14, 15, 16	−1.2 mV/°C

At constant temperature, voltage change as a function of current can be predicted from equation (3)

$$\Delta V_F = \frac{nKT}{q} \log_e \frac{I_{F(1)}}{I_{F(2)}} \quad (5)$$

where

V_F = forward voltage
I_F = forward current
n = constant

The values of n range from 1 to 3 for GaAs IREDs. Exact values may be obtained by characterizing the diode under the operating conditions to which it will be exposed.

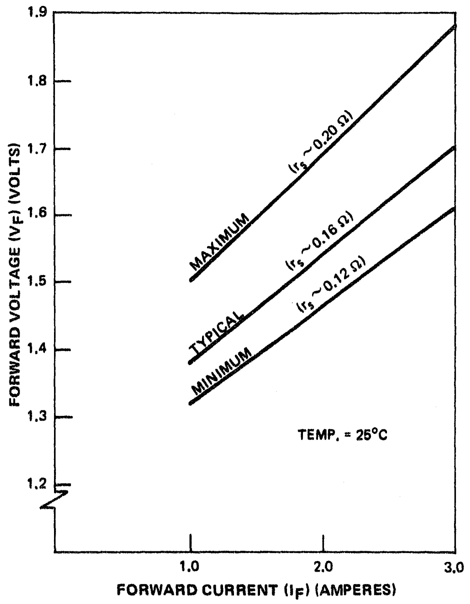

FIGURE 3. Forward Voltage-Forward Current Characteristics for TIXL16

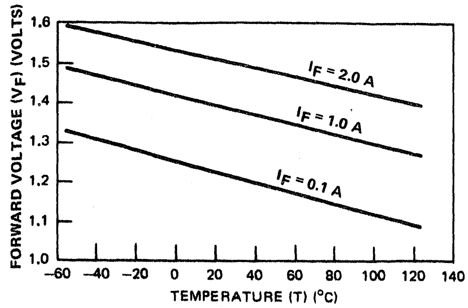

FIGURE 5. Forward Voltage-Heat Sink Temperature Characteristic For TIXL14 and TIXL15

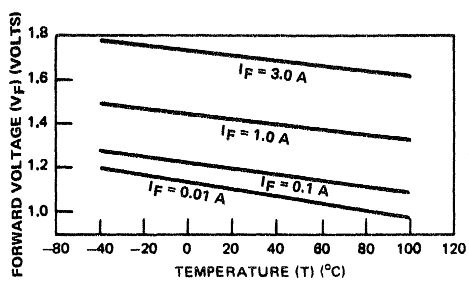

FIGURE 6. Forward Voltage-Heat Sink Temperature For TIXL16

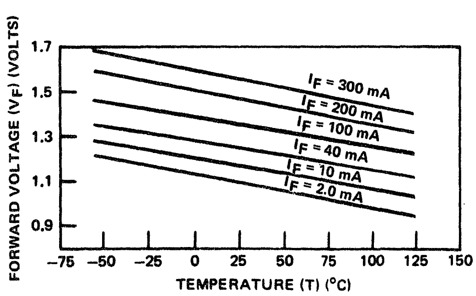

FIGURE 4. Forward Voltage-Heat Sink Temperature Characteristics For TIXL12 and TIXL13

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OPTICAL POWER

The optical power generated by GaAs infrared emitters is nearly a linear function of the forward bias current when operated above very low currents and below the maximum rated current.

The optical power becomes more linear with the bias current as the temperature is decreased. Table III shows the observed $\Delta P/\Delta I$ in the linear operating region.

Table III

Device Type	ΔP/ΔI (mW/mA)
TIXL 12, 13	0.2
TIXL 14, 15	0.1
TIXL 16	0.15

Decreasing the temperature will cause the diode to become more efficient and thereby increase the optical power for any given forward bias current. Therefore, by the use of cooling equipment, the optical power can be increased above the rated powers, if space and external power requirements permit. The bias current can safely be increased to the level above which additional bias current does not increase optical power.

Optical power as a function of temperature and bias current is presented in Figures 7, 8, and 9.

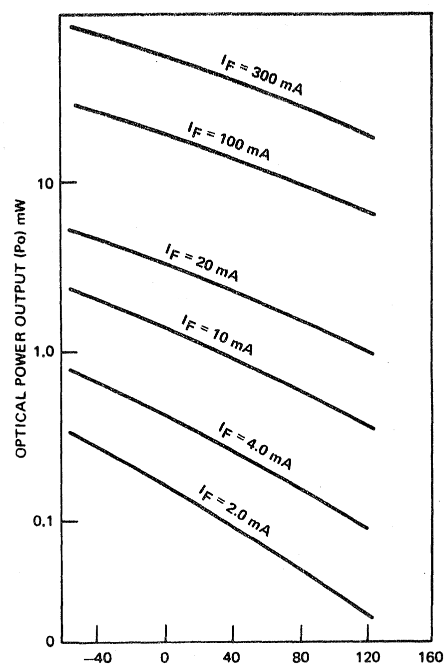

FIGURE 7. Optical Power Output-Heat Sink Temperature For TIXL12

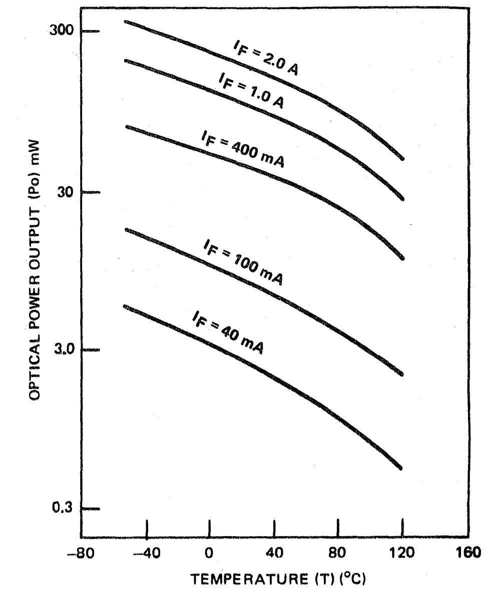

FIGURE 8. Optical Power Output-Heat Sink Temperature For TIXL14

An approximation that can be used when designing with IRED's is the optical power will increase by a factor of 2 when the temperature is decreased by 80°C. The optical power will decrease by 0.5 when the temperature is increased by 80°C. The reference of unity optical power is the optical power observed at 25°C.

The TIXL16 has been operated at liquid nitrogen temperature (–196°C), and the observed optical power as a function of bias current is shown in Figure 10.

Power Efficiency: The power efficiency of GaAs IRED's is defined as the optical power divided by the input current-voltage product. The power efficiency is a function of current.

Figures 11, 12, and 13 present the power efficiency capabilities of the GaAs solution grown devices. Figure 14 presents the power efficiency of the TIXL16 at liquid nitrogen (–196°C).

The maximum value of the TIXL12-TIXL16 series is slightly below the maximum recommended bias current rating.

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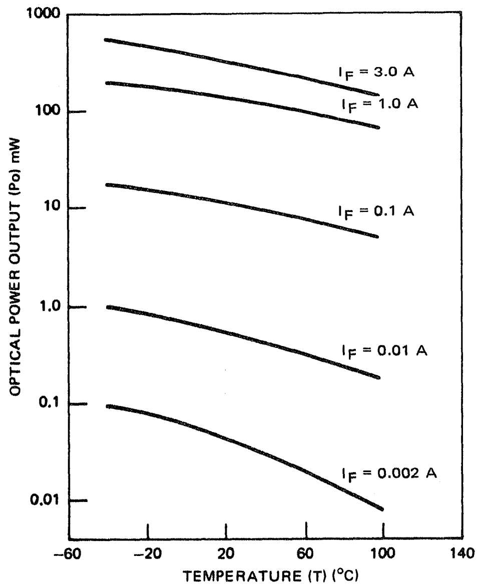

FIGURE 9. Optical Power Output-Heat Sink Temperature For TIXL16

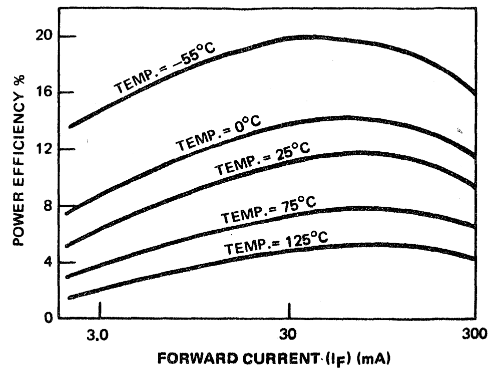

FIGURE 11. Power Efficiency-Forward Current For TIXL12

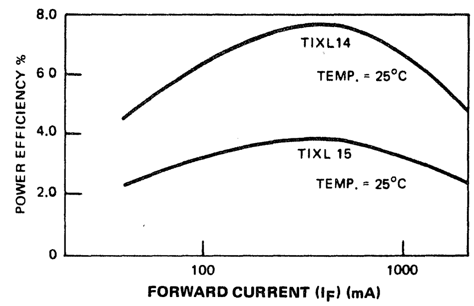

FIGURE 12. Power Efficiency-Forward Current For TIXL14 and TIXL15 at 25°C

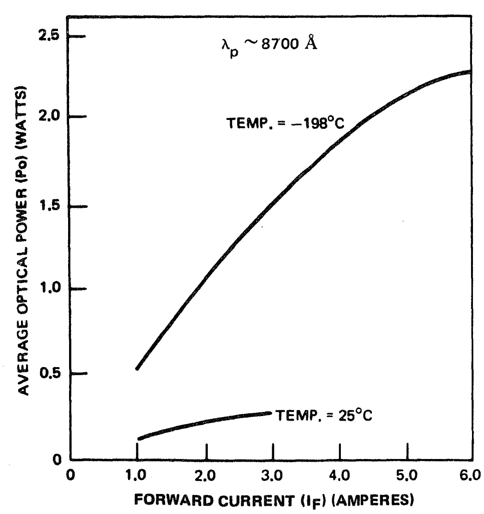

FIGURE 10. Average Optical Power-Forward Current For TIXL16 at 25°C and −196°C

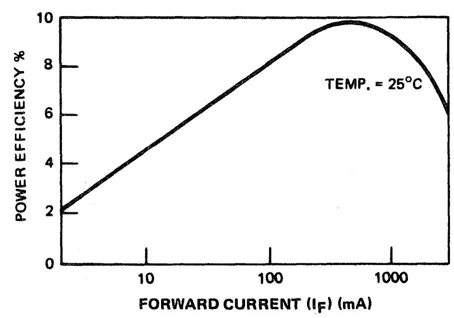

FIGURE 13. Power Efficiency-Forward Current For TIXL16 at 25°C

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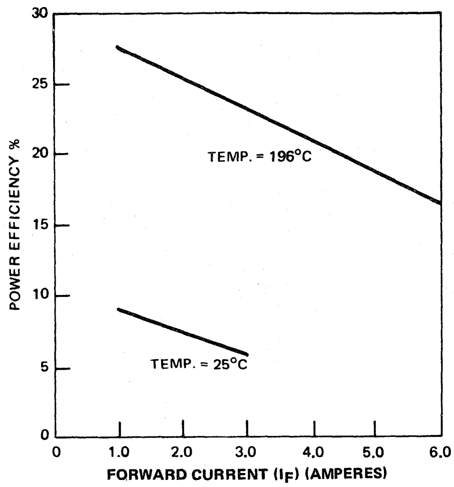


FIGURE 14. Power Efficiency-Forward Current For TIXL16 at 25°C and –196°C

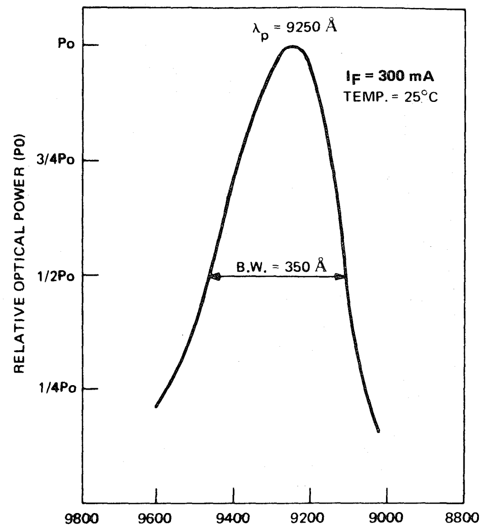


FIGURE 15. Typical Spectral Distribution For TIXL12

SPECTRAL DISTRIBUTION

The typical spectral distribution for the GaAs solution-grown infrared emitters is presented in Figures 15, 16, and 17.

The peak wavelength (λ_p) is a function of bias current and temperature. Table IV presents typical peak wavelength and bandwidths (half power points).

Table IV

Device Type	λ_p (Å)	$\Delta\lambda$ (Å)
TIXL 12, 13	9300	350
TIXL 14, 15	9300	350
TIXL 16	9300	350

For TIXL12-TIXL16 series an average change of 3Å/°C has been measured over the temperature of –50°C to +120°C. The bandwidth remains nearly constant in this temperature range.

Relative Intensity: Polar plots of typical relative intensity versus angular displacement are presented in Figures 18 and 19. Figure 20 presents what a reflector can do in aiding the designer when a narrow beam is required.

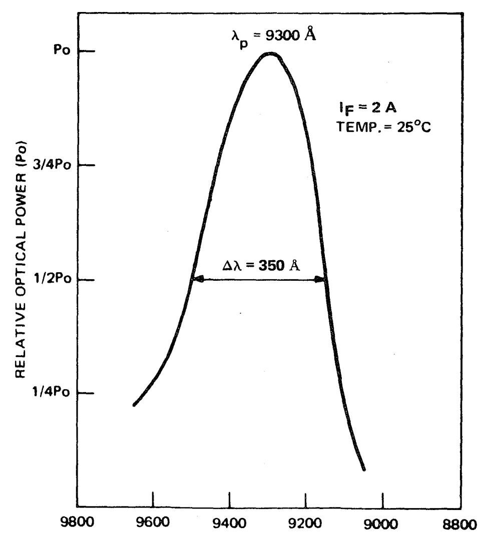


FIGURE 16. Typical Spectral Distribution For TIXL14

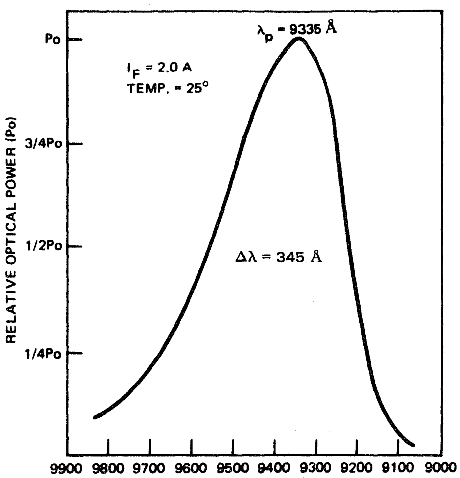


FIGURE 17. Typical Spectral Distribution For TIXL16

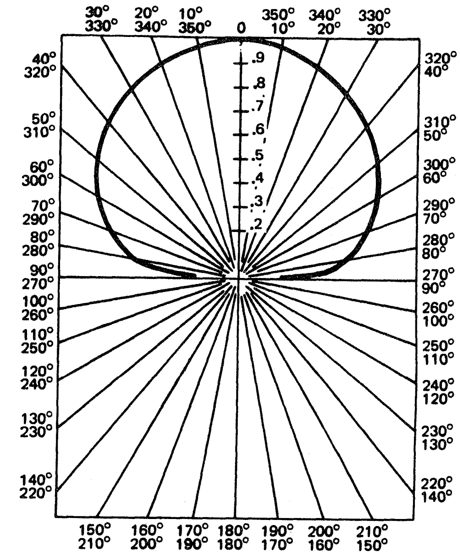


FIGURE 19. Relative Intensity-Angular Displacement For TIXL16

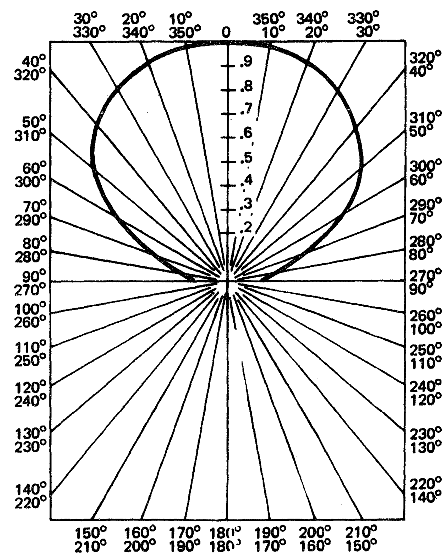


FIGURE 18. Relative Intensity-Angular Displacement For TIXL12, 13, 14, and 15

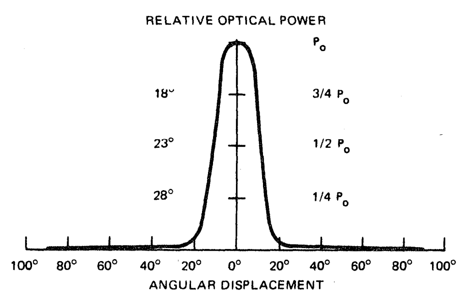
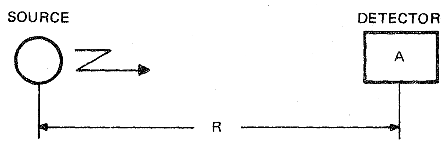


FIGURE 20. Beam Pattern For TIXL16 with Reflector

RADIANT INTENSITY

Radiant intensity is defined as radiant flux per unit solid angle in a given direction and is measured as watts/steradian.

One steradian is the solid angle subtended at the center of a sphere by a portion of the surface area equal to the square of the radius of the sphere. There are 4π steradians in a complete sphere. Radiant intensity can be measured in the following manner. Radiant energy from an emitter is beamed into an aperture of area A. The radiant flux at the aperture is measured by a detector.



The radiant intensity (I_e) is given by the following equation,

$$I_e = W/sr = \frac{P_o \text{ at detector}}{A/R^2} \qquad (6)$$

where

I_e = radiant intensity
A = aperture area
R = distance from source to detector

Minimum values in watts/steradian are presented in Table V for the TIXL12-TIXL16 series at their rated bias currents.

Table V

Device Type	mW/sr
TIXL 12	15.0
TIXL 13	7.0
TIXL 14	22.0
TIXL 15	11.0
TIXL 16	46.0

THERMAL RESISTANCE

The thermal resistance (in °C/W) can be defined as the temperature difference between two points or regions divided by the power dissipation under conditions of thermal equilibrium.

It is a difficult parameter to calculate accurately but can be measured with a reasonable degree of accuracy. The junction temperature can be approximated by

$$T_J = P \cdot R_{\theta JHS} + T_{HS} \qquad (7)$$

where

P = power input
$R_{\theta JHS}$ = junction-to-heat-sink thermal resistance
T_{HS} = heat-sink temperature

The method used to measure thermal resistance depends on the fact that the voltage across the P-N junction at a fixed forward current varies inversely and almost linearly with the temperature.

In practice, the diodes to be measured are first calibrated in an oven at a constant 5-mA current by plotting forward voltage drops at several temperatures. This gives a V_F-T_J calibration curve for each diode.

Each diode is then placed on a constant temperature heatsink and connected to the thermal resistance test set. The test set contains circuitry for interrupting the d.c. currents for periods of 100-μs at about one-percent duty cycle. During the 100-μs period, a 5-mA calibrating current is applied to the diode and the forward voltage is measured.

The temperature corresponding to this voltage is read from the V_F-T_J calibration curve. By taking power and temperature readings at several current levels, a plot of junction temperature versus applied power may be obtained as shown in Figures 21, 22, and 23.

FREQUENCY RESPONSE

Frequency response depends on the type technology and packaging techniques used.

The frequency response curves are shown in Figure 24. These curves were obtained by forward biasing the diodes at 50 mA and modulating the d.c. bias with a 10 mA peak-to-peak sine wave signal. The output of the emitters were detected with a high speed detector. Measured values of the rise and fall times of the output of the diode, as detected by the high speed detector are 250 nanoseconds and 300 nanoseconds respectively.

The frequency response of the TIXL12-TIXL16 series is lower than the response of other Texas Instruments IREDs.

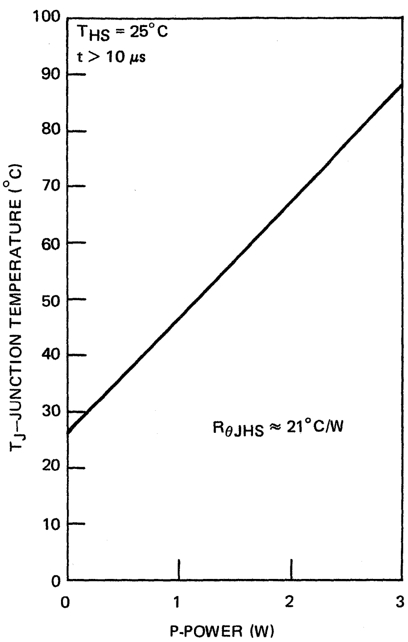


FIGURE 21. Thermal Resistance Characteristic for TIXL12 and TIXL13

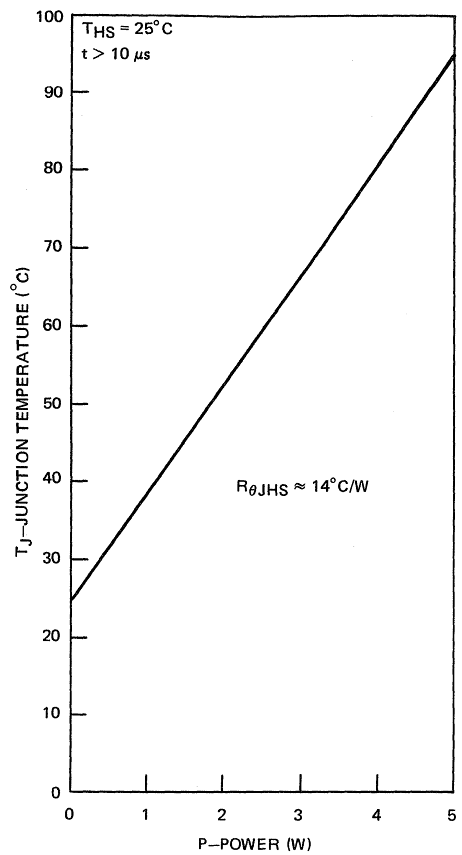


FIGURE 22. Thermal Resistance Characteristic for TIXL14 and TIXL15

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PACKAGE CONFIGURATION AND DESIGN

The TIXL12-TIXL16 series of IRED's are solution-grown P-N junctions isolated by mesa formation in the shape of 36-mil or 72-mil diameter hemispheres (Figure 25).

An alloyed P-type ohmic contact is applied to the top of the mesa. A N-type contact is applied to the surrounding area.

The TIXL12-TIXL15 series are mounted in a window package which has a 6-32 stud as the anode contact and a solder lug as the cathode contact. The series are normally hermetically sealed but may be left unsealed at customer request.

The TIXL16A, TIXL16B, and TIXL16C are mounted on a heavier stud package with no can. This provides a wider emission angle.

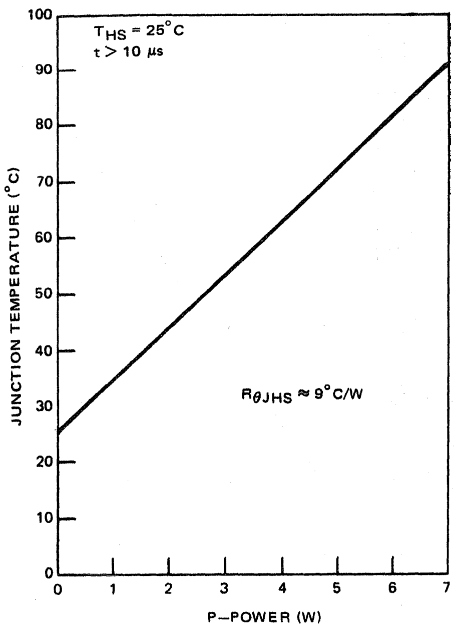


FIGURE 23. Thermal Resistance Characteristic for TIXL16A, TIXL16B, and TIXL16C

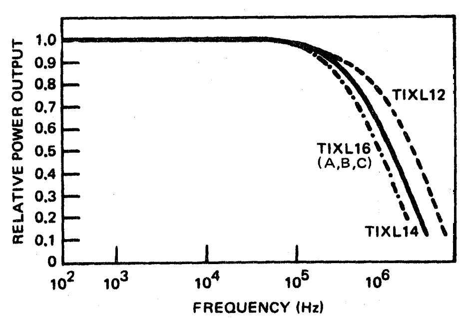


FIGURE 24. Frequency Response Characteristic for TIXL12, TIXL14, and TIXL16 (A, B, C)

The TIXL12 and TIXL13 devices have 36-mil-diameter hemispheres with rated optical powers of 40 mW and 20 mW at 300 mA forward bias current.

The TIXL14-TIXL15 devices have 72-mil-diameter hemispheres with rated optical powers of 60 mW and 30 mW at 1 ampere forward bias current.

The TIXL16A and TIXL16B devices have 72-mil diameter hemispheres with rated optical powers of 100 and 200 mW at 2 amperes forward bias current while the TIXL16C is selected to give 350 mW at 3 amperes.

The TIXL12,13,14,15 are capable of passing environmental tests in accordance with the following Mil-Std procedures:

Thermal shock:
Mil-Std-750A, method 1056.1, condition A.

Acceleration:
Mil-Std-750A, method 2006 at a level of 15,000 G's, Y_1 & Y_2 axis.

Hermetic Seal:
Mil-Std-202, method 112, condition C, except the leakage rate shall not exceed 50 X 10^{-8} ATM CC/sec.

Solderability:
Mil-Std-750A, method 2026 as appropriate with solder lug.

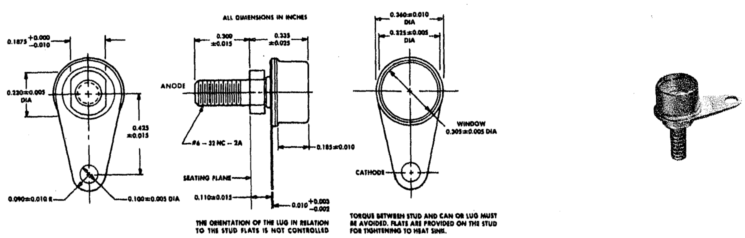
Vibration-Variable Frequency:
Mil-Std-750A, method 2056 30 G's.

Mechanical Shock:
Mil-Std-202, method 213 sawtooth pulse at 100G's.

Moisture Resistance (non-operating):
Mil-Std-750A, method 1021, except that lead fatigue test shall be omitted.

The TIXL16A, TIXL16B, and TIXL16C are capable of passing Mil-Std environmental testing where tests are compatible with devices that are not hermetically sealed.

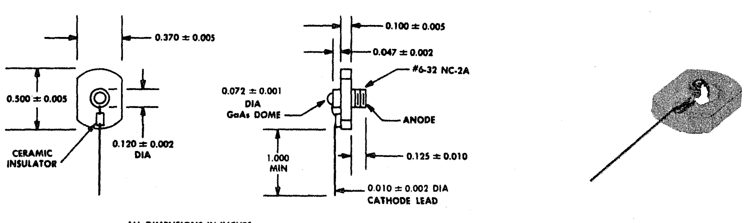
TIXL12, TIXL13, TIXL14, TIXL15
P-N GALLIUM ARSENIDE INFRARED EMITTING DIODES



The devices are in hermetically sealed packages with a flat glass window in the top of the case. The cathode is in electrical contact with the case and adjacent solder lug. The anode is in electrical contact with the stud, which is insulated from the case by a glass-to-metal seal. Soldered connections should not be made directly to the stud because of the low-thermal-resistance path between the stud and emitting element.

FIGURE 25A.

TYPE TIXL16A, TIXL16B, TIXL16C
P-N GALLIUM ARSENIDE INFRARED EMITTING DIODES



The diode is mounted on a copper stud header to provide efficient heat sinking. The anode is in electrical contact with the copper stud. The cathode lead is a varnished 0.01-inch copper wire secured to the stud by a metalized ceramic insulator. Soldered connections should not be made directly to the stud because of the low-thermal-resistance path to the emitting element.

FIGURE 25B.

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TYPICAL GaAs EMITTER CIRCUITS

For best performance emitters should be biased from a current source rather than a voltage source. A simple method is to place a resistor in series with a voltage power supply to approximate a current source.

Proper heat sinking is also required to insure that excessive heating does not occur and cause power output of the diodes to decrease.

Typical circuits using infrared emitters are shown in Figure 26. These circuits can serve as building blocks for more sophisticated and optimum circuits.

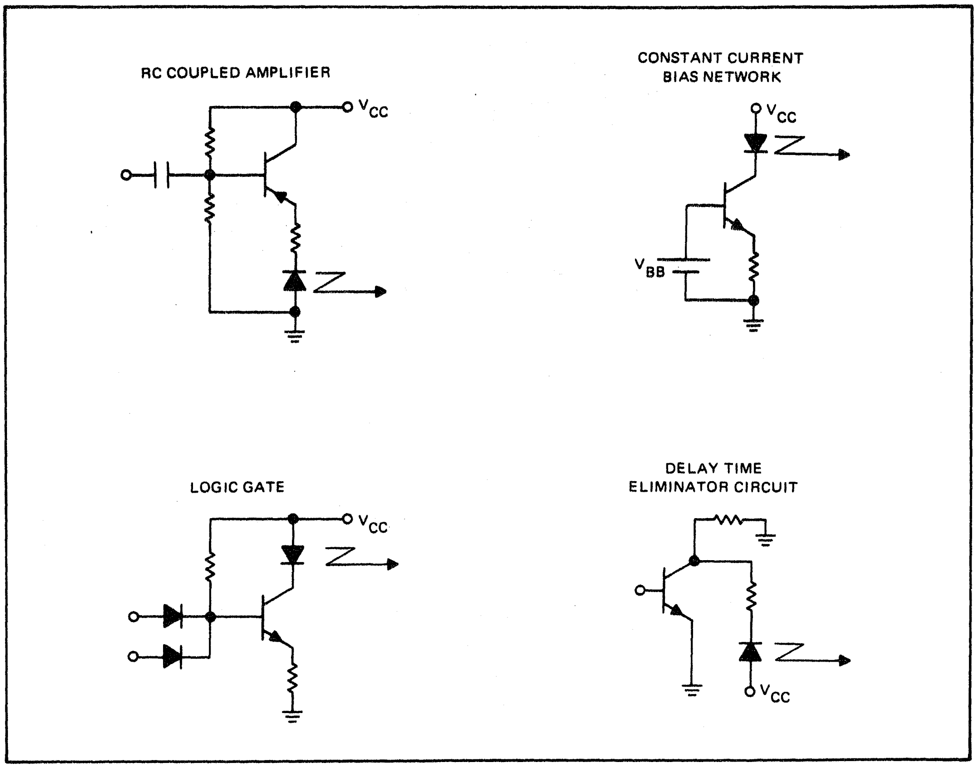

FIGURE 26. Typical Emitter Circuits

SUGGESTED FURTHER READING

Biard et al, "Optoelectronics as Applied to Functional Electronic Blocks", *Proceedings of the IEEE*, Vol. 52, No. 12, December 1964, Ppp. 1529-1536.

Millman and Halkias, "Electronic Devices and Circuits", McGraw-Hill, pp. 132-133.

Shortley and Williams, "Elements of Physics", Prentice-Hall, pp. 437-439.

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TIXL27 GaAs SPONTANEOUS INFRARED EMITTER

The TIXL27 GaAs spontaneous infrared emitter is essentially a solution-grown P-N junction. The output of the device is 15 mW minimum with 20 mW being typical at the rated forward current. The device emits in the near-infrared region.

This report presents basic information necessary to utilize this high-power low-cost industrial emitter. Included in this discussion are the theory of operation, device performance including forward voltage, optical power, spectral distribution, radiance, radiant intensity, thermal impedance, pulse mode operation and optical design considerations plus typical mechanical specification and application data.

THEORY OF OPERATION

The TIXL27 GaAs spontaneous infrared emitter is a solution grown P-N junction in the shape of a 16-mil-square wafer. The wafer is mounted on a TO-5 stud header and encapsulated in an epoxy dome.

When the P-N junction is forward biased, electrons from the N-region are injected into the P-region and radiant quanta (photons) are generated through recombination. The radiant energy emitted is in the near-infrared region.

A flat geometry GaAs source emitting into an air media has a critical angle that can be described by

$$\sin\theta_c = \frac{N_1}{N_2} \qquad (1)$$

where N_1 = index of refraction of air = 1

N_2 = index of refraction of GaAs = 3.6

θ_c = critical angle = 16.2°.

Any radiant energy generated that strikes the surface of the wafer at an angle greater than the critical angle will not escape the material but will be reflected internally. This is shown in Figure 1.

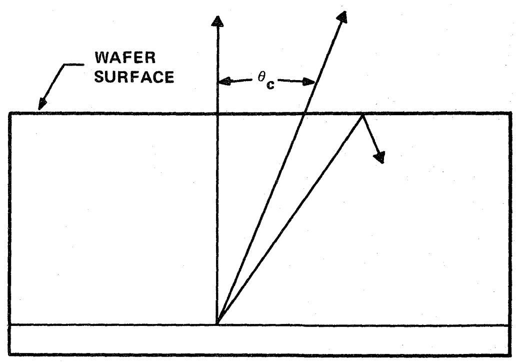

FIGURE 1. Angle of Light Determines if it Escapes or is Reflected Internally

The critical angle of the TIXL27 wafer has been changed by placing epoxy on the wafer. Since the index of refraction of the epoxy is 1.5, the critical angle changes from 16.2° to 24.6°. The improvement factor can be calculated as follows:

$$\alpha = \frac{1 - \cos\theta_2}{1 - \cos\theta_1} = \frac{1 - \cos 24.6}{1 - \cos 16.2} = \qquad (2)$$

$$\frac{1.0 - 0.91}{1.0 - 0.96} = 2.25$$

The improvement factor is valid only when the radiant energy that is emitted from the P-N junction can be transmitted through the epoxy and into the air.

The external quantum efficiency of the device can be described as the ratio of optical current output (photons per second) divided by forward input current.

$$\eta_S = \frac{I_\phi}{I_F} \qquad (3)$$

1

DEVICE PERFORMANCE

Forward Voltage

At a constant temperature, the voltage change as a function of current can be predicted from equation (4):

$$\Delta V_F = \frac{nKT}{q} \log e \frac{I_{F_1}}{I_{F_2}} \quad (4)$$

where V_F = forward voltage

I_F = forward current

$\frac{KT}{q} \approx 26$ mV

n = constant

The value of n ranges from 1 to 3 for the TIXL27 with n being larger at small forward bias currents. Exact values for n may be obtained by characterizing the diode under the operating conditions to which it will be exposed.

The typical distribution of the forward voltage at the rated current of 300 mA will range from 1.3 volts to a maximum of 2.2 volts.

Optical Power

The TIXL27 generates an optical output power of 15 mW minimum. The optical output power approximates a linear function of the forward bias current when operated above a few milliamperes and at or below the maximum specified forward current. Figure 2 shows relative optical power versus forward drive current.

The optical output power can be described by Equation (5):

$$P_o = I_\phi E$$

where I_ϕ = optical output current = $\eta_s I_F$ (5)

$$E = \frac{1.24}{\lambda}$$

λ = peak wavelength in micrometers.

The optical power of the TIXL27 varies inversely with temperature. A typical curve of optical output power versus temperature is shown in Figure 3.

Spectral Distribution

The distribution of emission wavelengths of the TIXL27 is narrow; half-power wavelengths are typically separated by 450 angstroms. The peak wavelength ranges from 9300 to 9450 angstroms when operated at rated forward current at 25°C stud temperature. The peak wavelength (λp) is a function of forward bias current and temperature. The change in wavelength of peak intensity versus case (stud) temperature is shown in Figure 4.

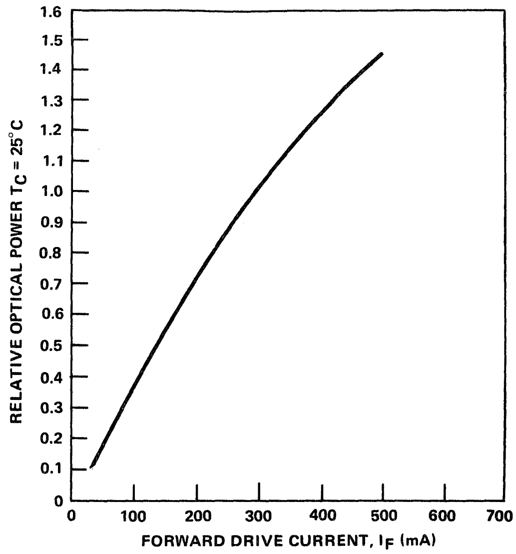

FIGURE 2. Relative Optical Power versus Forward Drive Current for TIXL 27. T = 25°C.

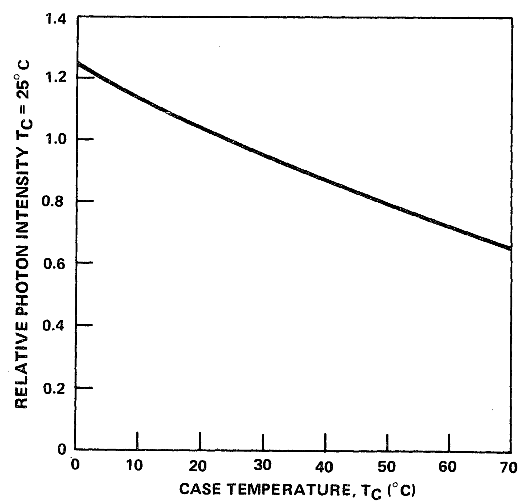

FIGURE 3. Relative Photon Intensity versus Case Temperature

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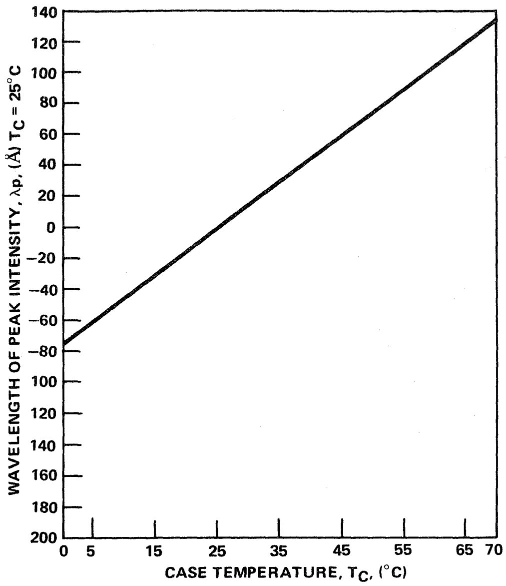

FIGURE 4. Change in Wavelength of Peak Intensity versus Case (Stud) Temperature. $I_F = 300$ mA.

Radiance

Radiance (L_e) is defined as radiant intensity emitted per unit area. In the case of the TIXL27, the radiance can be calculated by using Equations (5) – (8):

$$P_o = I_\phi E$$

where I_ϕ = optical output current = $\eta_s I_F$ (5)

$$E = \frac{1.24}{\lambda}$$

λ = peak wavelength in micrometers.

$$L_e = \frac{P_o}{\Omega - A} \qquad (6)$$

where P_o = total optical power

Ω = solid angle of emission in Steradians

A = Area of active region in cm^2.

For the TIXL27,

$$L_e = \frac{15 \text{ X } 10^{-3} W}{(2\pi) sr (1.650 \text{ X } 10^{-6} cm^2)} = \qquad (7)$$

$$\frac{15 \text{ X } 10^{-3} W}{(6.28)(1.65 \text{ X } 10^{-3})\ sr\ (cm^2)}$$

$$L_e = \frac{15 \text{ W}}{10.4 \text{ sr} - cm^2} = 1.44 \text{ W/sr } (cm^2). \qquad (8)$$

It should be pointed out that this is the worst case because the TIXL27 does not emit uniformly into 2π steradians but into a solid angle less than 2π.

Radiant Intensity

The radiant intensity of an isotropic radiator is equal in all directions, therefore, the radiant intensity is equal to

$$I_e = \frac{P}{2\pi} \qquad (9)$$

where I_e = radiant intensity W/sr

P = total optical power – W

However, most GaAs infrared emitters are not perfect isotropic radiators and the radiant intensity is higher on the optical axis or within a few degrees of the optical axis. Figure 5 shows a typical intensity pattern for the TIXL27.

Thermal Resistance

The thermal resistance of the TIXL27 is typically in the range of 12°C/W. The device wafer is mounted directly to the stud which when heatsinked properly can be approximated to the first order as an infinite heatsink. It is important to note that the thermal resistance is a very difficult parameter to calculate and measured values from different groups of processed material may have a wide distribution.

Pulse Mode Operation

The TIXL27 is capable of being pulsed at relatively high peak currents. The limiting factor, as it is in most pulsed mode applications, is the interfaces and not the P-N junction–the power density gets so large in the bonding wire or the contact pad that catastrophic failures occur. For example, a 1-mil gold wire that is 0.5 inches long has a power density of approximately 4200 W/cm^3 with 300 mA flowing through it. However, by increasing the current to 1 amp, the power density increases to approximately 47,000 W/cm^3.

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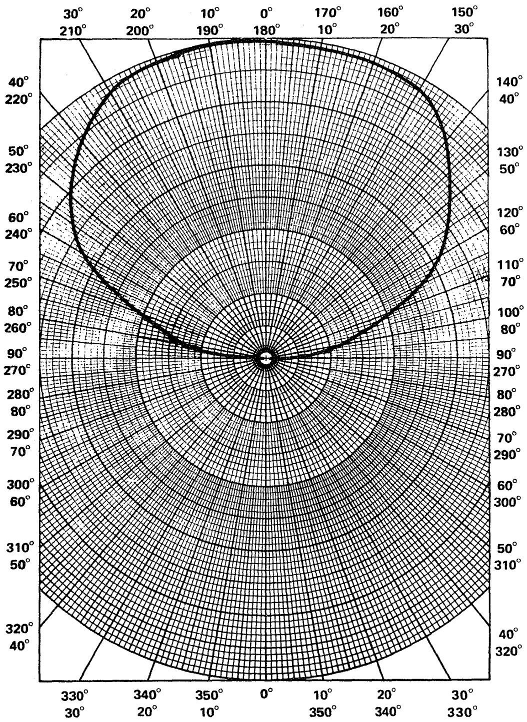

FIGURE 5. A Typical Intensity Pattern for the TIXL 27

There are tradeoffs that must be considered when operating in the pulse mode such as duty cycle, repetition rate, and peak current. The peak current can be approximated with reasonable accuracy by using

$$I_{FM} = (I_F \max)/D = I_F \max \left(\frac{T}{t}\right) \qquad (10)$$

where I_{FM} = maximum peak current

I_F max = Maximum rated continuous forward current

D = duty cycle

T = period of frequency

t = diode "on" time

However, careful judgement should be used to ensure that the peak current does not exceed a level that will cause the bonding wires to open. The TIXL27 should not be exposed to peak pulses of current greater than 4 amperes with an appropriate duty cycle. Figure 6 shows typical peak power

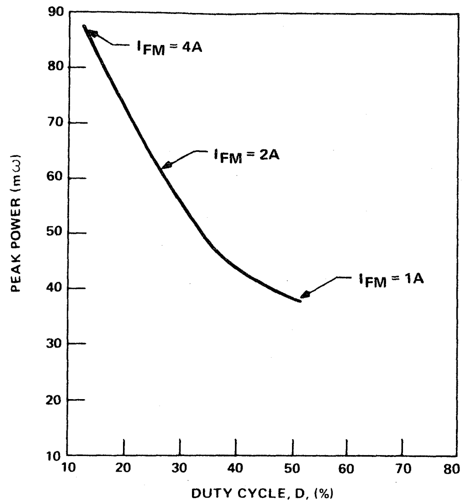

FIGURE 6. Typical Peak Power of TIXL 27 at 10 kHz with Various Peak Current Levels at Various Duty Cycles

obtained when the device was operated at a frequency of 10 kHz with current levels of 1 ampere, 2 amperes and 4 amperes at respective duty cycles of 50%, 25%, and 12.5% – higher current pulses than equation (10) defines.

Optical Design Considerations

Since the TIXL27 emits into such a large pattern (approximately 2π steradians), it is necessary to use some form of optics to collect and direct that portion of the optical power that will be used.

The amount of optical power collected can be determined quickly once the optics have been defined. The following is an example that illustrates the éffect of the $f/\#$ of the lens on the power transmitted.

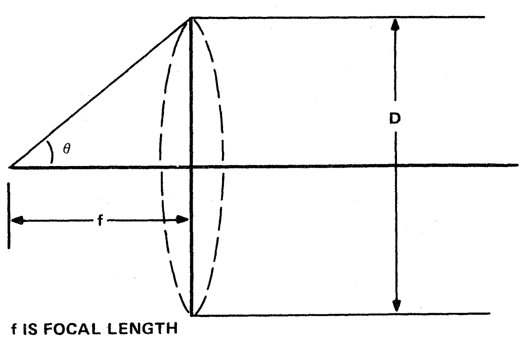

FIGURE 7. Typical Optical Collection Configuration

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$$P_t = P_o \left(\frac{\Omega_c}{\Omega_e}\right) \eta_t = \qquad (11)$$

$$P_o \left(\frac{2\pi\,(1 - \mathrm{Cos}\,\theta)}{2\pi}\right) \eta_t$$

where P_t = optical power transmitted in the beam of the collection optics.

Ω_c = the solid angle of collection in steradians.

Ω_e = the solid angle of emission in steradians.

η_t = the transmission efficiency of the lens.

θ = the half angle of the collection cone.

P_o = the total radiated optical power.

Table 1

f/#	θ (°)	1 – Cos θ	P_t (mW)
1.0	26.6	0.1	1.5
1.4	19.6	0.06	0.8
2.0	14.0	0.03	0.45
2.8	10.2	0.02	0.3
4.0	7.0	0.01	0.15

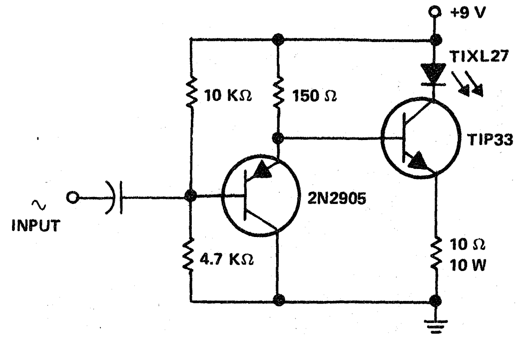


FIGURE 8. An Economical Circuit for Modulating a TIXL 27

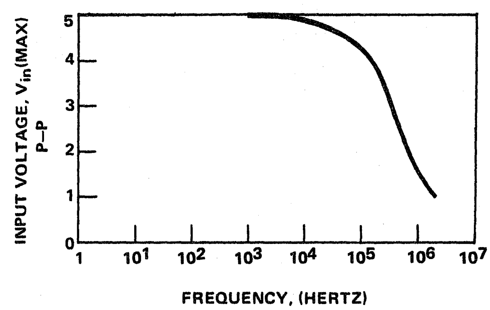


FIGURE 9. Maximum Frequency for Circuit in Figure 8

TYPICAL APPLICATION DATA

Figure 8 shows an economical approach for modulating a TIXL27. This circuit features excellent bandwidth as well as high peak currents. Figures 9, 10, and 11 show the performance data for the circuit shown in Figure 8.

MECHANICAL DATA

The device is encapsulated and mounted on a stud header. The cathode is in electrical contact with the solder lug. The anode is in electrical contact with the stud, which is insulated from the case by a glass-to-metal seal. Soldered connections should not be made directly to the stud because of the low-thermal-resistance path between stud and emitting element.

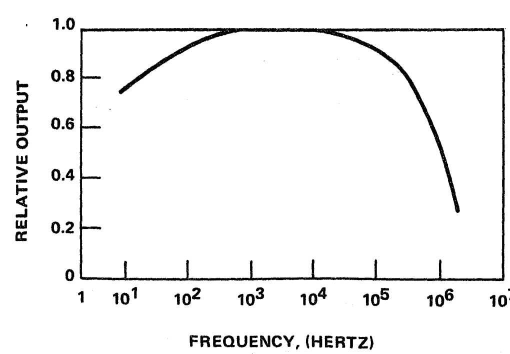


FIGURE 10. Frequency Response of IRED in Circuit of Figure 8.

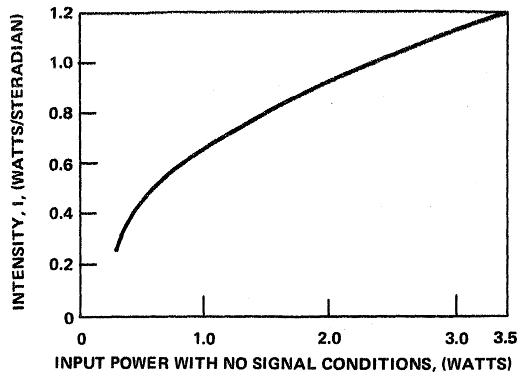
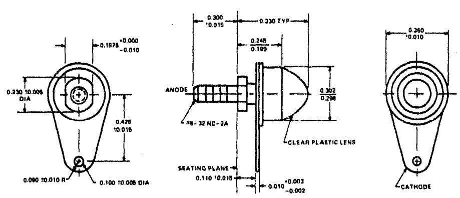


FIGURE 11. Intensity versus Input Power for Circuit in Figure 8 When it is Used with an f/1.6 Lens Which has a 29-Millimeter Diameter



NOTES: A. The orientation of the lug in relation to the stud flats is not controlled.
B. Torque between stud and lug must be avoided. Flats are provided on the stud for tightening to heat sink.

ALL DIMENSIONS IN INCHES

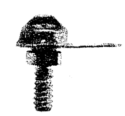


FIGURE 12. Mechanical Specifications for TIXL 27

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HIGH-RESISTIVITY SILICON PHOTODIODES

INTRODUCTION

Texas Instruments high-resistivity silicon photodiodes provide outstanding performance in the visible and near-infrared regions of the electromagnetic spectrum. These photodiodes ususally have a large active area and operate at a large reverse bias. The principal characteristics of these devices are

- High speed at near-IR wavelengths
- Good responsivity at 1.06 μm
- Large output signal
- Dark current relatively independent of reverse bias

The principal applications for these photodiodes include the following:

- Laser Guidance Systems
- Optical Proximity Fuzes
- Laser Distance-Measuring Systems
- Laser Detection and Optical Alignment in Long-Range Optical Communications
- High-Speed Character Recognition Equipment

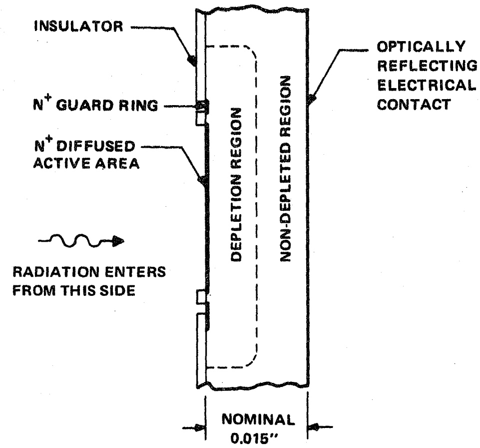

FIGURE 1—BASIC STRUCTURE OF THE HIGH-RESISTIVITY SILICON PHOTODIODE

HIGH-RESISTIVITY SILICON PHOTODIODE STRUCTURE

The basic structure of a high-resistivity silicon photodiode is shown in Figure 1. This is a planar diffused diode with an N+ guard-ring and is operated in a reverse-bias mode. The outstanding features of this structure are the following:

- High reliability due to silicon-nitride-passivated planar-diffused junction
- High signal-to-noise ratio due to anti-reflection coating on the detector element and low dark current resulting from the N+ guard ring
- Simplified optical systems as a result of large areas. Active areas up to 0.650-inch diameter are available in standard products.
- Flexibility in system design. Single or multiple detector elements on a single substrate are available in standard and custom-designed packages.
- Wide depletion region at relatively low voltages due to the use of high-resistivity silicon
- Low capacitance and good responsivity at 1.06 μm because of the wide depletion width.
- High speed as a result of all hole-electron pairs being generated in the high-field drift region.

ELECTRICAL CHARACTERISTICS

Typical characteristics for high-resistivity silicon photodiode detectors at 25°C and 150 V reverse bias are:

- Responsivity (A/W)
  - 0.34 at 1.06 μm
  - 0.68 at 0.9 μm
  - 0.20 at 0.6 μm
  - 0.02 at 0.4 μm
- Rise and Fall Times ≈ 7 ns at 1.06 μm
- Capacitance ≈ 35 pF/cm^2
- Dark Current < 1 μA/cm^2
- Crosstalk between elements in detector arrays <1 percent

Figure 2 is a graph of responsivity versus wavelength for a typical detector.

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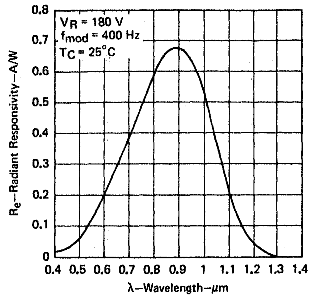


FIGURE 2—RELATIVE SPECTRAL RESPONSE CURVE

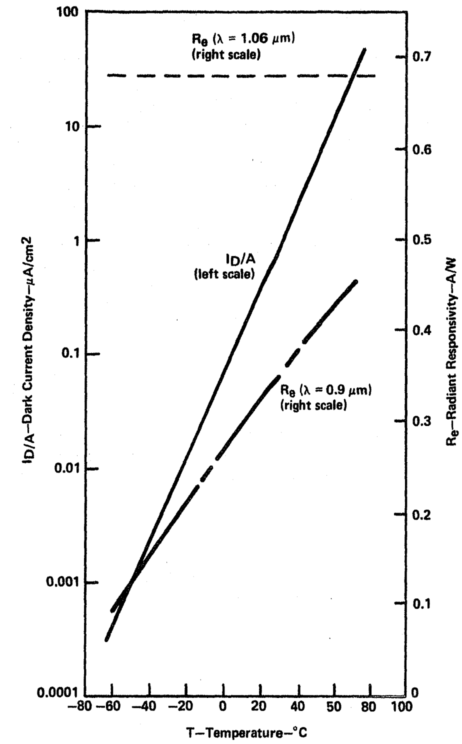


FIGURE 4—DARK CURRENT AND RADIANT RESPONSIVITY VERSUS TEMPERATURE

These devices have a maximum operating voltage greater than 300 volts, well in excess of the voltage required for full depletion. A plot of the typical dark current versus reverse voltage is shown in Figure 3. Dark current versus temperature and the effect of temperature on the responsivity at 0.9 μm and at 1.06 μm are shown in Figure 4.

A capacitance versus reverse voltage plot of a detector is shown in Figure 5. Note that the detector capacitance becomes independent of the voltage when the detector is fully depleted.

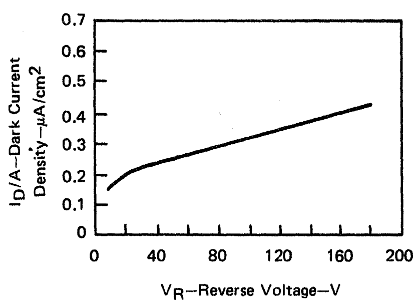


FIGURE 3—DARK CURRENT VERSUS REVERSE VOLTAGE

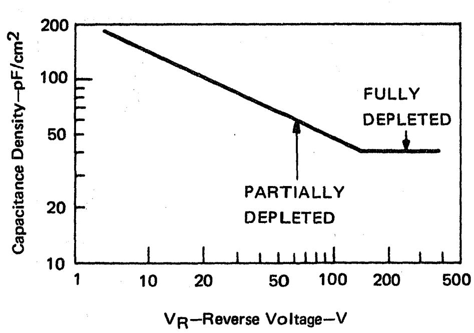


FIGURE 5—CAPACITANCE VERSUS REVERSE VOLTAGE

HIGH-RESISTIVITY PHOTODIODE DETECTOR OPERATION

The basic operation of a high-resistivity photodiode is illustrated in Figure 6. When a reverse bias is applied to the diode, the depletion region expands, and a high field is formed within the detector. The conditions shown in Figure 6 are for a reverse bias of about 100 volts. The electron-hole pairs that are created in the depletion region by the incoming electromagnetic radiation have a high drift velocity, which results in fast and efficient collection. The use of high-resistivity silicon allows a wide depletion width and low capacitance at moderate voltages. The depletion region expands to the back contact at a reverse bias of about 150 volts. Good responsivity at longer wavelengths requires a wide depletion region because of the low absorption coefficient of silicon at these wavelengths.

The basic electrical model for these detectors operated under a reverse bias is shown in Figure 7.

Texas Instruments is currently engaged in the volume production of these detectors (Figure 8) to military specifications and is actively pursuing various development programs for both commercial and military applications.

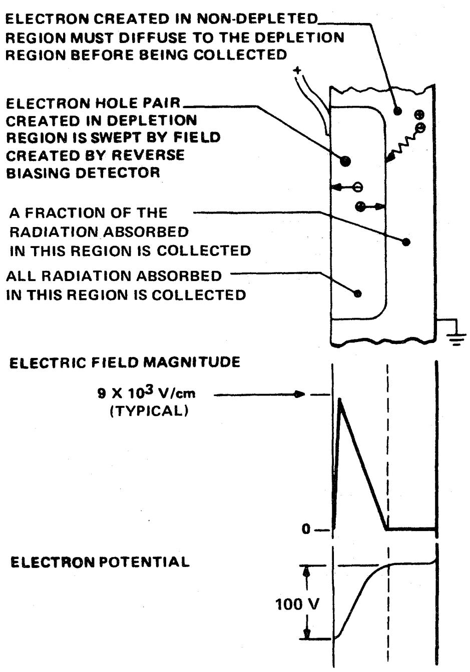
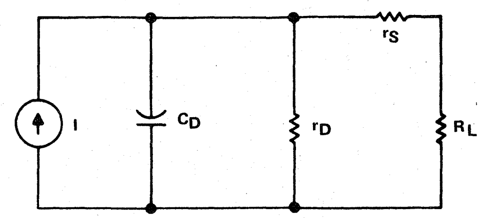


FIGURE 6—BASIC OPERATION OF THE HIGH-RESISTIVITY SILICON PHOTODIODE



where I = photoelectric current generated
C_D = diode capacitance
r_D = diode differential resistance
r_S = diode series resistance, and
R_L = load resistor

FIGURE 7—BASIC ELECTRICAL MODEL FOR THE HIGH-RESISTIVITY SILICON PHOTODIODE OPERATING IN REVERSE-BIAS MODE

The generated current I, in amperes, is given by

$$I = R_e P A$$

where R_e = responsivity in amperes/watt
P = power of incident radiation in watts/cm^2, and
A = junction area in cm^2.

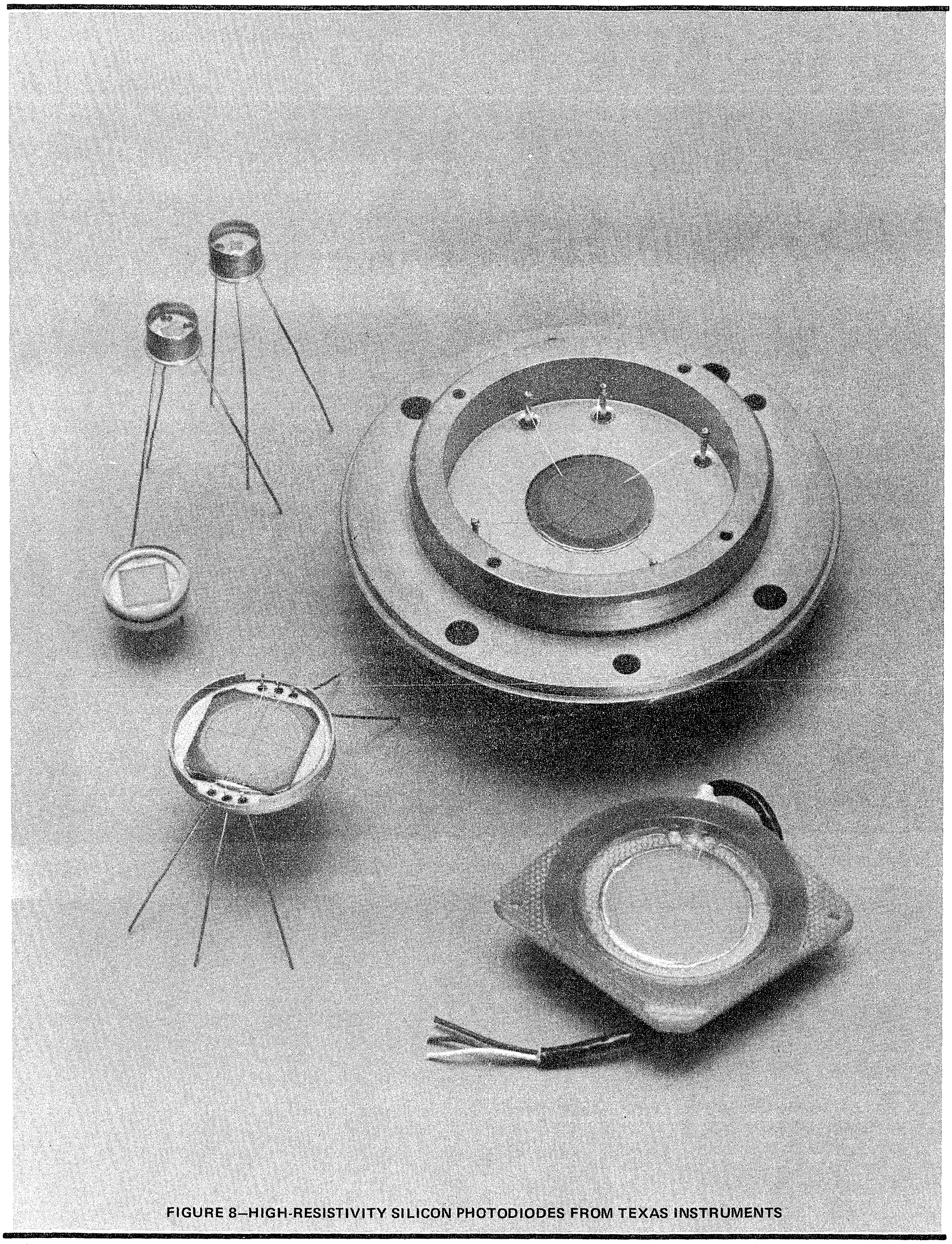


FIGURE 8—HIGH-RESISTIVITY SILICON PHOTODIODES FROM TEXAS INSTRUMENTS