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INTERACTIVE data book

OPTICAL SENSORS

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VISHAY INTERTECHNOLOGY, INC.

DATA BOOK

OPTICAL SENSORS

Reflective

Transmissive

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Optical Sensors

Databook

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NOTICE

OZONE DEPLETING SUBSTANCES POLICY STATEMENT

It is the policy of Vishay Semiconductor GmbH to

1. Meet all present and future national and international statutory requirements.
2. Regularly and continuously improve the performance of our products, processes, distribution and operating systems with respect to their impact on the health and safety of our employees and the public, as well as their impact on the environment.

It is particular concern to control or eliminate releases of those substances into the atmosphere which are known as ozone depleting substances (ODSs).

The Montreal Protocol (1987) and its London Amendments (1990) intend to severely restrict the use of ODSs and forbid their use within the next ten years. Various national and international initiatives are pressing for an earlier ban on these substances.

Vishay Semiconductor GmbH has been able to use its policy of continuous improvements to eliminate the use of ODSs listed in the following documents.

1. Annex A, B and list of transitional substances of the Montreal Protocol and the London Amendments respectively
2. Class I and II ozone depleting substances in the Clean Air Act Amendments of 1990 by the Environmental Protection Agency (EPA) in the USA
3. Council Decision 88/540/EEC and 91/690/EEC Annex A, B and C (transitional substances) respectively.

Vishay Semiconductor GmbH can certify that our semiconductors are not manufactured with ozone depleting substances and do not contain such substances.

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Reflective Optical Sensors

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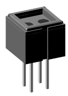
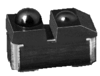
	CNY70	0 to 4.5	< 0.5	Phototransistor		55
	TCND3000	10 to 20	20	PIN Photodiode	Interface ASIC E909.01 not included Surface mount	60
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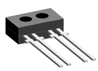
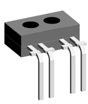
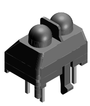
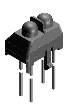
	TCRT1000	0.2 to 4	1	Phototransistor		75
	TCRT1010	0.2 to 4	1	Phototransistor	Bend leads	75
	TCRT5000	0.2 to 14	2.5	Phototransistor		80
	TCRT5000L	0.2 to 14	2.5	Phototransistor	Long leads	80

* Relative output current > 20 %

Transmissive Optical Sensors

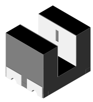
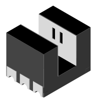
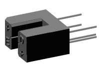
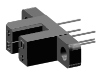
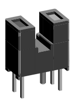
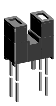
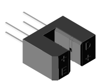
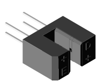
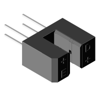
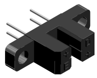
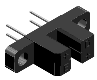
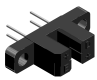
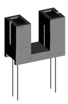
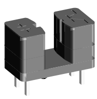
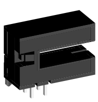
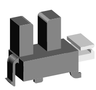
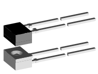
Image	Part Number	Gap mm	Aperture mm	Detector Device	Remarks	Page
	TCPT1200	2	0.3	Phototransistor	Surface mount	93
	TCUT1200	2	0.3	Phototransistor	Dual channel Surface mount	137
	TCSS1100	3.1	1	Photo Schmitt-Trigger	Digital interface	100
	TCSS2100	3.1	1	Photo Schmitt-Trigger	Digital interface Mounting flanges	100
	TCST1030	3.1	no	Phototransistor		106
	TCST1030L	3.1	no	Phototransistor	Long leads	106
	TCST1103	3.1	1	Phototransistor		114
	TCST1202	3.1	0.5	Phototransistor		114
	TCST1300	3.1	0.25	Phototransistor		114

Image	Part Number	Gap mm	Aperture mm	Detector Device	Remarks	Page
	TCST2103	3.1	1	Phototransistor	Mounting flanges	114
	TCST2202	3.1	0.5	Phototransistor	Mounting flanges	114
	TCST2300	3.1	0.25	Phototransistor	Mounting flanges	114
	TCST1210	5	0.5	Phototransistor		121
	TCST1230	2.8	0.5	Phototransistor		126
	TCST5250	2.7	0.5	Phototransistor		131
	TCYS5201	5	0.5	Photo Schmitt-Trigger	Digital interface Connector (3 pin)	144
	TCZT8020	Custom Design	no	Phototransistor	Matched Emitters and Detectors	147

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Symbols and Terminology

A Anode, anode terminal

A ampere
SI unit of electrical current

A Radiant sensitive area
That area which is radiant sensitive for a specified range

a Distance e.g. between the emitter (source) and the detector

B Base, base terminal

BER Bit Error Rate

bit/s Data rate or signaling rate
1000 bit/s = 1 kbit/s, 10^6 bit/s = 1 Mbit/s

C Capacitance
Unit: F (farad) = C/V

C coulomb
C = s x A

C Cathode, cathode terminal

C Collector, collector terminal

°C degree Celsius
Celsius temperature, symbol t, and is defined by the quantity equation
$t = T - T_0$.
The unit of Celsius temperature is the degree Celsius, symbol °C. The numerical value of a Celsius temperature t expressed in degrees Celsius is given by
t / °C = T / K – 273.15
It follows from the definition of t that the degree Celsius is equal in magnitude to the kelvin, which in turn implies that the numerical value of a given temperature difference or temperature interval whose value is expressed in the unit degree Celsius (°C) is equal to the numerical value of the same difference or interval when its value is expressed in the unit kelvin (K).

cd candela
SI unit of luminous intensity. The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 x 1012 hertz and that has a radiant intensity in that direction of
1/683 watt per steradian. (16^{th} General Conference of Weights and Measures, 1979)
1 cd = 1 lm · sr^{-1}

C_D Diode capacitance
Total capacitance effective between the diode terminals due to case, junction and parasitic capacitances

Cj Junction capacitance
Capacitance due to a pn junction of a diode, decreases with increasing reverse voltage

CTR Current Transfer Ratio
Ratio between output and input current

D, d Distance

d, Ø Apparent of virtual source size (of an emitter)
The measured diameter of an optical source used to calculate the eye safety laser class of the source. See IEC60825-1

E Emitter
Emitter terminal (phototransistor)

E_A Illumination at standard illuminant A According to DIN 5033 and IEC 306-1, illumination emitted from a tungsten filament lamp with a color temperature Tf = 2855.6 K which is equivalent to standard illuminant A
Unit: lx (Lux) or klx

$E_{A\ amb}$
Ambient illumination at standard illuminant A

echo - off
Unprecise term to describe the behavior of the output of IrDA, transceivers during transmission. "echo – off" means that by blocking the receiver the output Rxd is quiet during transmission.

echo - on
Unprecise term to describe the behavior of the output of IrDA, transceivers during transmission. "echo – on" means that the receiver output Rxd is active but often undefined during transmission. For correct data reception after transmission the receiver channel must be cleared during the latency period

E_e, E irradiance (at a point of a surface)
Quotient of the radiant flux $d\Phi_e$ incident on an element of the surface containing the point, by the area dA of that element. Equivalent definition. Integral, taken over the hemisphere visible from the given point, of the expression $L_e \cdot \cos\theta \cdot d\Omega$, where L_e is the radiance at the given point in the various directions of the incident elementary beams of solid angle dΩ, and θ is the angle between any of these beams and the normal to the surface at the given point.

$$E_e = \frac{d\Phi_e}{dA} = \int_{2\pi sr} (L_e \cdot \cos\theta \cdot d\Omega)$$

unit : W x m^{-2}

E_v, E illuminance (at a point of a surface) Quotient of the luminous flux $d\Phi_v$ incident on an element of the surface containing the point, by the area dA of that element. Equivalent defnition. Integral, taken over the hemisphere visible from the givenpoint, of the expression
$L_v \cdot \cos\theta \cdot d\Omega$, where L_v is the luminance at the given point in the various directions of the incident elementary beams of solid angle $d\Omega$, and θ is the angle between any of these beams and the normal to the surface at the given point.
unit: $lx = lm \times m^{-2}$

F Farad
unit: F = C/V

f Frequency
unit: s^{-1}, Hz (Hertz)

f_c, f_{cd} Cut-off frequency – detector devices The frequency at which, for constant signal modulation depth of the input radiant power, the demodulated signal power has decreased to ½ of its low frequency value. Example: The incident radiation generates a photocurrent or a photo voltage 0.707 times the value of radiation at f = 1 kHz
(3 dB signal drop, other references may occur as e.g. 6 dB or 10 dB) FIR As SIR, data rate 4 Mbit/s

f_s Switching frequency

FIR As SIR, data rate 4 Mbit/s

Ia Light current
General: Current which flows through a device due to irradiation/illumination

I_B Base current

I_{BM} Base peak current

I_C Collector current

I_{ca} Collector light current
Collector current under irradiation
Collector current which flows at a specified illumination/irradiation

I_{CEO} Collector dark current, with open base Collector-emitter dark current
For radiant sensitive devices with open base and without illumination/radiation
(E = O)

I_{CM} Repetitive peak collector current

Idle Mode of operation where the device (e.g. a transceiver) is fully operational and expecting to receive a signal for operation e.g in case of a transceiver waiting to receive an optical input or to send an optical output as response to an applied electrical signal.

I_e, I radiant intensity (of a source, in a given direction)
Quotient of the radiant flux d Φe leaving the source and propagated in the element of solid angle d . containing the given direction, by the element of solid angle.
$I_e = d\Phi_v/d\Omega$
unit: $W.sr^{-1}$
Note: The radiant intensity I_e of emitters is typically measured with an angle
< 0.01 sr on mechanical axis or off-axis in the maximum of the irradiation pattern.

I_F Continuous forward currentThe current flowing through a diode in the forward direction

I_{FAV} Average (mean) forward current

I_{FM} Peak forward current

I_{FSM} Surge forward current

I_{FT} Threshold forward current
The minimum current required to switch from the off-state to the on-state

I_k Short-circuit current That value of the current which flows when a photovoltaic cell or a photodiode is short circuited (R_L << R_i) at its terminals

I_o dc output current

I_{ph} Photocurrent
That part of the output current of a photoelectric detector, which is caused by incident radiation.

I_R Reverse current, leakage current
Current which flows through a reverse biased semiconductor pn-junction IR Infrared

I_{ra} Reverse current under irradiation Reverse light current which flows due to a specified irradiation/illumination in a photoelectric device
$I_{ra} = I_{ro} + I_{ph}$

IrDA, Infrared Data Association
No profit organization generating infrared data communication standards

IRED Infrared emitting diode, see LED

I_{ro} Reverse dark current
Dark current Reverse current flowing through a photoelectric device in the absence of irradiation

IrPHY version 1.0
SIR IrDA, data communication specification covering data rates from 2.4 kbit/s to 115.2 kbit/s and a guaranteed operating range more than one meter in a cone of
± 15°.

IrPHY version 1.1
MIR and FIR were implemented in the IrDA, standard with the version 1.1, replacing version 1.0

IrPHY version 1.2
adding the SIR Low Power Standard to the IrDA, standard, replacing version 1.1. The SIR Low Power Standard describes a current saving implementation with reduced range (20 cm to other Low Power Devices and 30 cm to full range devices).

IrPHY version 1.3
extended the Low Power Option to the higher bit rates of MIR and FIR replacing version 1.2.

IrPHY version 1.4
VFIR was added, replacing version 1.3

I_{SB} Quiescent current

I_{SD} Supply current in dark ambient

I_{SH} Supply current in bright ambient

I_T On-state current
The permissible output current under stated conditions

I_v, I luminous intensity (of a source, in a given direction)
Quotient of the luminous flux $d\Phi_v$ leaving the source and propagated in the element of solid angle $d\Omega$ containing the given direction, by the element of solid angle.
$I_e = d\Phi_v/d\Omega$
unit: $cd.sr^{-1}$
Note: The luminous intensity I_v of emitters is typically measured with an angle < 0.01 sr on mechanical axis or off-axis in the maximum of the irradiation pattern.

K luminous efficacy of radiation
Quotient of the luminous flux Φ_v by the corresponding radiant flux Φ_e:
$K = \Phi_v / \Phi_e$
unit: $lm.W^{-1}$
Note. - When applied to monochromatic radiations, the maximum value of $K(\lambda)$ is denoted by the symbol K_m.
$K_m = 683\ lm.W^{-1}$ for $\nu_m = 540 \times 10^{12}$ Hz ($\lambda_m \approx 555$ nm) for photopic vision.
$K'_m = 1700\ lm.W^{-1}$ for $\lambda'_m \approx 507$ nm for scotopic vision. For other wavelengths :
$K(\lambda) = K_m V(\lambda)$ and $K'(\lambda) = K'_m V'(\lambda)$.

K The kelvin, SI-unit of thermodynamic temperature, is the fraction 1/273.15 of the thermodynamic temperature of the triple point of water (13th CGPM (1967), Resolution 4). The unit kelvin and its symbol K should be used to express an interval or a difference of temperature.
Note : In addition to the thermodynamic temperature (symbol T), expressed in kelvins, use is also made of Celsius temperature (symbol t) defined by the equation
$t = T - T_0$, where $T_0 = 273.15$ K by definition. To express Celsius temperature, the unit "degree Celsius," which is equal to the unit "kelvin" is used; in this case, "degree Celsius" is a special name used in place of "kelvin". An interval or difference of Celsius temperature can, however, be expressed in kelvins as well as in degrees Celsius.

Latency
Receiver Latency Allowance (in ms or µs) is the maximum time after a node ceases transmitting before the node's receiving recovers its specified sensitivity

LED and IRED
Light Emitting Diode
Semiconductor device converting electrical energy into optical radiation. The term LED is correct only for visible radiation, because light is defined as visible radiation (see Radiation and Light). For infrared emitting diodes the term IRED is the correct term. Nevertheless it is common but not correct to use "LED" also for IREDs.

L_e; L radiance (in a given direction, at a given point of a real or imaginary surface)
Quantity defined by the formula

$$L_e = \frac{d\Phi_v}{dA \cdot \cos\theta \cdot d\Omega} ,$$

where $d\Phi_e$ is the radiant flux transmitted by an elementary beam passing through the given point and propagating in the solid angle $d\Omega$ containing the given direction; dA is the area of a section of that beam containing the given point; θ is the angle between the normal to that section and the direction of the beam.
unit: $W \cdot m^{-2} \cdot sr^{-1}$

lm Lumen
Unit for luminous flux

lx Lux
Unit for illuminance

m meter
SI unit of length

M_e; M
radiant exitance (at a point of a surface) - Quotient of the radiant flux $d\Phi_e$ leaving an element

of the surface containing the point, by the area dA of that element. Equivalent definition. Integral, taken over the hemisphere visible from the given point, of the expression $L_e \cdot \cos\theta \cdot d\Omega$, where L_e is the radiance at the given point in the various directions of the emitted elementary beams of solid angle $d\Omega$, and θ is the angle between any of these beams and the normal to the surface at the given point.

$$M_e = \frac{d\Phi_e}{dA} = \int_{2\pi sr} L_e \cdot \cos\theta \cdot d\Omega$$

unit: $W.m^{-2}$

MIR Medium speed IR, as SIR, with the data rate 576 kbit/s to 1152 kbit/s

Mode Electrical input or output port of a transceiver device to set the receiver bandwidth

N.A. Numerical Aperture
N.A. = sin $\alpha/2$
Term used for the characteristic of sensitivity or intensity angles of fiber optics and objectives

NEP Noise Equivalent Power

P_{tot} Total power dissipation

P_v Power dissipation, general

Radiation and Light
visible radiation
Any optical radiation capable of causing a visual sensation directly.
Note: - There are no precise limits for the spectral range of visible radiation since they depend upon the amount of radiant power reaching the retina and the responsivity of the observer. The lower limit is generally taken between 360 nm and 400 nm and the upper limit between 760 nm and 830 nm.

Radiation and Light
optical radiation
Electromagnetic radiation at wavelengths between the region of transition to X-rays (λ = 1 nm) and the region of transition to radio waves (λ = 1 mm).

Radiation and Light IR
infrared radiation
Optical radiation for which the wavelengths are longer than those for visible radiation. Note. - For infrared radiation, the range between 780 nm and 1 mm is commonly sub-divided into :
IR-A 780 nm to 1400 nm
IR-B 1.4 µm to 3 µm
IR-C 3 µm to 1 mm

R_D Dark resistance

R_F Feedback resistor

R_i Internal resistance

R_{is} Isolation resistance

R_L Load resistance

R_S Serial resistance

R_{sh} The shunt resistance of a detector diode is the dynamic resistance of the diode at zero bias. Typically it is measured at a voltage of 10 mV forward or reverse, or peak-to-peak

R_{thJA} Thermal resistance, junction to ambient

R_{thJC} Thermal resistance, junction to case

RXD Electrical data output port of a transceiver device

s second
SI-unit of time 1 h = 60 min = 3600 s.

S Absolute sensitivity
Ratio of the output value Y of a radiant-sensitive device to the input value X of a physical quantity: S = Y/X
Units: E.g. A/lx, A/W, $A/(W/m^2)$

S Displacement

$s(\lambda_p)$ Spectral sensitivity at a wavelength λ_p

$s(\lambda)$ Absolute spectral sensitivity at a wavelength λ
The ratio of the output quantity y to the radiant input quantity x in the range of wavelengths λ to $\lambda + \Delta\lambda$
$s(\lambda) = dy(\lambda)/dx(\lambda)$
e.g., the radiant power $\Phi_e(\lambda)$ at a specified wavelength λ falls on the radiationsensitive area of a detector and generates a photocurrent I_{ph}. $s(\lambda)$ is the ratio between the generated photocurrent Iph and the radiant power $\Phi_e(\lambda)$ which falls on the detector.
$s(\lambda) = I_{ph} / \Phi_e(\lambda)$
Unit: A/W

$s(\lambda)_{rel}$ Spectral sensitivity, relative
Ratio of the spectral sensitivity $s(\lambda)$ at any considered wavelength to the spectral sensitivity $s(\lambda_0)$ at a certain wavelength λ_0 taken as a reference
$s(\lambda)_{rel} = s(\lambda)/s(\lambda_0)$

$s(\lambda_0)$ Spectral sensitivity at a reference wavelength λ_0

SC Electrical input port of a transceiver device to set the receiver sensitivity

SD Electrical input port of a transceiver device to shut down the transceiver

Shutdown
Mode of operation where a device is switched to a sleep mode (shut down) by an external sig-

nal or after a quiescent period keeping some functions alive to be prepared for a fast transition to operating mode. Might be in some cases identical with "Standby"

SIR Serial Infrared, used to describe infrared data transmission up to and including 115.2 kbit/s. SIR IrDA, data communication covers 2.4 kbit/s to 115.2 kbit/s, equivalent to the basic serial infrared standard introduced with the physical layer version IrPhy version 1.0

Split power supply
Term for using separated power supplies for different functions in transceivers. Receiver circuits need well-controlled supply voltages. IRED drivers don't need a controlled supply voltage but need much higher currents. Therefore it safes cost not to control the IRED current supply and have a separated supply. For that some modified design rules have to be taken into account for designing the ASIC. This is used in nearly all Vishay transceivers and is described in US-Patent No. 6,157,476

sr steradian (sr)
SI unit of solid angle Ω
Solid angle that, having its vertex at the centre of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere. (ISO, 31/1-2.1, 1978)
Example:
The unity solid angle, in terms of geometry, is the angle subtended at the center of a sphere by an area on its surface numerically equal to the square of the radius (see figures below) Other than the figures might suggest, the shape of the area doesn't matter at all. Any shape on the surface of the sphere that holds the same area will define a solid angle of the same size. The unit of the solid angle is the steradian (sr). Mathematically, the solid angle is dimensionless, but for practical reasons, the steradian is assigned.

Standby
Mode of operation where a device is prepared to be quickly switched into an idle or operating mode by an external signal.

T Period of time (duration)

T Temperature
0 K = – 273.15 °C
Unit: K (kelvin),

t Temperature
°C (degree Celsius)
Instead of t sometimes T is used not to mix up Temperature T with Time t

t Time

T_{amb} Ambient temperature
If self-heating is significant: temperature of the surrounding air below the device, under conditions of thermal equilibrium. If self-heating is insignificant: air temperature in the surroundings of the device

T_{amb} Ambient temperature range
As an absolute maximum rating: The maximum permissible ambient temperature range

T_C,T_K Temperature coefficient
The ratio of the relative change of an electrical quantity to the change in temperature (ΔT) which causes it under otherwise constant operating conditions T_c Colo(u)r temperature The temperature of a Planckian radiator whose radiation has the same chromaticity as that of a given stimulus.
unit : K
Note: - The reciprocal colo(u)r temperature is also used, unit K^{-1}.

T_{case} Case temperature
The temperature measured at a specified point on the case of a semiconductor device. Unless otherwise stated, this temperature is given as the temperature of the mounting base for devices with metal can

t_d Delay time

t_f Fall time
The time interval between the upper specified value and the lower specified value on the trailing edge of the pulse.
Note: It is common to use a 90 % value of the signal for the upper specified value and a 10 % value for the lower specified value.

T_j Junction temperature
The spatial mean value of the temperature during operation. In the case of phototransistors, it is mainly the temperature of the collector junction because its inherent temperature is the maximum.

t_{off} Turn-off time The time interval between the upper specified value on the trailing edge of the applied input pulse and the lower specified value an the trailing edge of the output pulse.
$t_{off} = t_{d(off)} + t_f$

t_{on} Turn-on time
The time interval between the lower specified

value on the trailing edge of the applied input pulse and the upper specified value an the trailing edge of the output pulse.
$t_{on} = t_{d(on)} + t_f$

t_p Pulse duration
The time interval between the specified value on the leading edge of the pulse and the specified value an the trailing edge of the output pulse.
Note: In most cases the specified value is 50 % of the signal.

t_{pi} Input pulse duration

t_{po} Output pulse duration

t_r Rise time
The time interval between the lower specified value and the upper specified value on the trailing edge of the pulse.
Note: It is common to use a 90 % value of the signal for the upper specified value and a 10 % value for the lower specified value ts Storage time

t_s Storage time

T_{sd} Soldering temperature
Maximum allowable temperature for soldering with a specified distance from the case and its duration

T_{stg} Storage temperature range
The temperature range at which the device may be stored or transported without any applied voltage

TXD Electrical data input port of a transceiver device

V volt

$V(\lambda)$ Standard luminous efficiency function for photopic vision (relative human eye sensitivity)

$V(\lambda)$, $V'(\lambda)$
spectral luminous efficiency (of a monochromatic radiation of wavelength λ) $V(\lambda)$ for photopic vision; $V'(\lambda)$ for scotopic vision)
Ratio of the radiant flux at wavelength λ_m to that at wavelength λ such that both radiations produce equally intense luminous sensations under specified photometric conditions and λ_m is chosen so that the maximum value of this ratio is equal to 1.

V_{cc} Supply Voltage (positive)

V_{CEsat}
Collector-emitter saturation voltage
The saturation voltage is the dc voltage between collector and emitter for specified (saturation) conditions, i.e., IC and EV (E_e or IB), whereas the operating point is within the saturation region.

V_{dd} Supply Voltage (positive)

V_F Forward voltage
The voltage across the diode terminals which results from the flow of current in the forward direction

VFIR As SIR, data rate 16 Mbit/s

V_{logic} Reference voltage for digital data communication ports

V_O Output voltage

ΔV_O Output voltage change
(differential output voltage)

V_{OC} Open circuit voltage
The voltage measured between the photovoltaic cell or photodiode terminals at a specified irradiance/illuminance (high impedance voltmeter!)

V_{OH} Output voltage high

V_{OL} Output voltage low

V_{ph} Photovoltage
The voltage generated between the photovoltaic cell or photodiode terminals due to irradiation/ illumination

V_R Reverse voltage (of a junction)
Applied voltage such that the current flows in the reverse direction.

V_R Reverse (breakdown) voltage
The voltage drop which results from the flow of a defined reverse current

V_S Supply voltage

V_{ss} (most negative) Supply Voltage (in most cases : Ground)

$+/- \varphi_{1/2}$
Angle of half transmission distance

η quantum efficiency

$\theta_{1/2}$ $+/- \varphi = \alpha/2$
half – intensity angle
In a radiation diagram, the angle within which the radiant (or luminous) intensity is greater than or equal to half of the maximum intensity
Note: IEC60747-5-1 is using $\theta_{1/2}$. In Vishay data sheets mostly $+/- \varphi = \alpha/2$ is used

$\theta_{S/2}$ $+/- \varphi = \alpha/2$
half – sensitivity angle
In a sensitivity diagram, the angle within which the sensitivity is greater than or equal to half of the maximum sensitivity.
Note: IEC60747-5-1 is using $\theta_{1/2}$. In Vishay data sheets mostly $+/- \varphi = \alpha/2$ is used

Ω solid angle, see sr, steradian for IEC60050(845)-definition
The space enclosed by rays, which emerge from a single point and lead to all the points of a closed curve. If it is assumed that the apex of the cone formed in this way is the center of a sphere with radius r and that the cone intersects with the surface of the sphere, then the size of the surface area (A) of the sphere subtending the cone is a measure of the solid angle .
$\Omega = A/r^2$
The full sphere is equivalent to 4π sr A cone with an angle of $\alpha/2$ forms a solid angle of
$\Omega = 2\pi(1\text{-}\cos\,\alpha/2) = 4\pi\sin2\,\alpha/4$
unit: sr (steradian)

λ_m Wavelength of the maximum of the spectral luminous efficiency function $V(\lambda)$

$\Delta\lambda$ Range of spectral bandwidth (50 %)
The range of wavelengths where the spectral sensitivity or spectral emission remains within 50 % of the maximum value

F_e; F; P
radiant flux; radiant power (F_e; F; P)
Power emitted, transmitted or received in the form of radiation. unit: W
W = Watt

Φ_v; Φ; luminous flux
Quantity derived from radiant flux Φ_e by evaluating the radiation according to its action upon the CIE standard photometric observer. For photopic vision

$$\Phi_v = K_m \int_0^{\infty} \frac{d\Phi_e\lambda}{d\lambda} \cdot V(\lambda)d\lambda \quad ,$$

where $\frac{d\Phi_e\lambda}{d\lambda}$ is the spectral distribution of

the radiant flux and $V(\lambda)$ is the spectral luminous efficiency.
unit : lm
lm: lumen
K_m = 683 lm/W:
Note: - For the values of K_m (photopic vision) and K'm (scotopic vision), see IEC60050 (845-01-56).

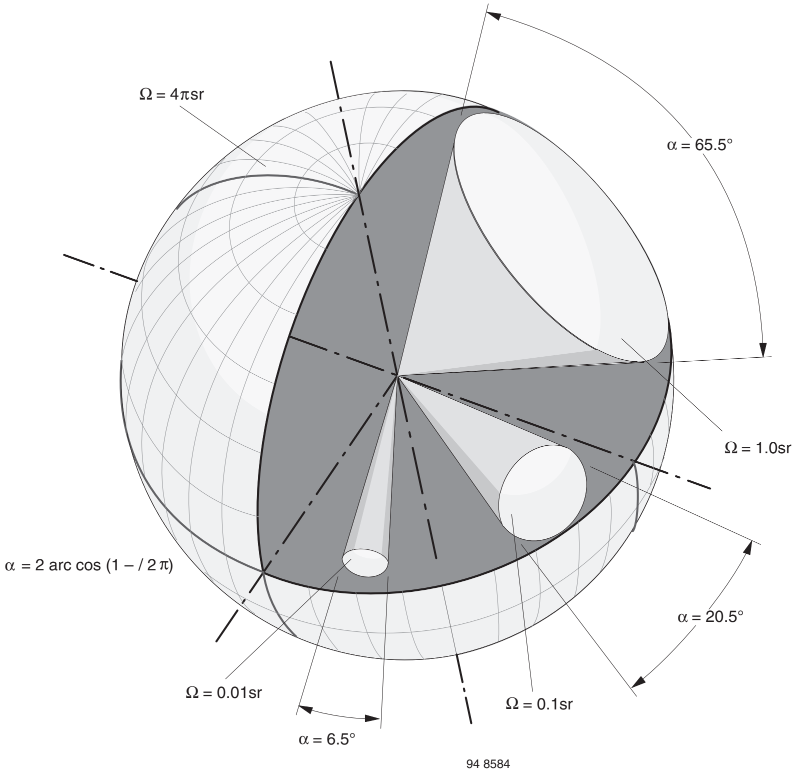
λ Wavelength, general

λ_c Centroid Wavelength
Centroid wavelength λ_c of a spectral distribution, which is calculated as "centre of gravity wavelength" according to

$$\lambda_c = \int_{\lambda_1}^{\lambda_2} \lambda \cdot S_x(\lambda)d\lambda / \int_{\lambda_1}^{\lambda_2} S_x \cdot (\lambda)d\lambda$$

λ_D Dominant wavelength

λ_p Wavelength of peak sensitivity or emission



The nomenclature, symbols, abbreviations and terms inside the Vishay Semiconductors IRDC Data book is based on ISO and IEC standards.

The special optoelectronic terms and definitions are referring to the IEC Multilingual Dictionary (Electricity, Electronics and Telecommunications), Fourth edition (2001-01), IEC50 (Now: IEC60050). The references are taken from the current editions of IEC60050 (845), IEC60747-5-1 and IEC60747-5-2. Measurement conditions are based on IEC and other international standards and especially guided by IEC60747-5-3.

Editorial notes: Due to typographical limitations variables cannot be printed in an italics format, which is usually mandatory. Our booklet in general is using American spelling. International standards are written in UK English. Definitions are copied without changes from the original text. Therefore these may contain British spelling.

Definitions

Radiant and Luminous Quantities and Their Units.

These two kinds of quantities have the same basic symbols, identified respectively, where necessary, by the subscript e (energy) or v (visual), e.g.Φ_e, Φ_V. See note.

Note: Photopic and scotopic quantities. - Luminous (photometric) quantities are of two kinds, those used for photopic vision and those used for scotopic vision. The wording of the definitions in the two cases being almost identical, a single definition is generally sufficient with the appropriate adjective, photopic or scotopic added where necessary.

The symbols for scotopic quantities are prime (Φ'_V, I'_V, etc), but the units are the same in both cases.

In general, optical radiation is measured in radiometric units. Luminous (photometric) units are used when optical radiation is weighted by the sensitivity of the human eye, correctly spoken, by the CIE standard photometric observer (Ideal observer having a relative spectral responsivity curve that conforms to the V(λ) function for photopic vision or to the V'(λ) function for scotopic vision, and that complies with the summation law implied in the definition of luminous flux).

Note: With a given spectral distribution of a radiometric quantity the equivalent photometric quantity can be evaluated. However, from photometric units without knowing the radiometric spectral distribution in general one cannot recover the radiometric quantities.

Radiometric Terms, Quantities and Units

The radiometric terms are used to describe the quantities of optical radiation.

The relevant radiometric units are:

Radiometric Term	Symbol	Unit	Reference
Radiant power, Radiant flux	Φ_e	W	IEC50 (845-01-24)
Radiant intensity	I_e	W/sr	IEC50 (845-01-30)
Irradiance	E_e	W/m^2	IEC50 (845-01-37)
Radiant Exitance	M_e	W/m^2	IEC50 (845-01-47)
Radiance	L_e	$W/(sr{*}m^2)$	IEC50 (845-01-34)

Table 1: Radiometric Quantities and Units

Photometric Terms, Quantities and Units

The photometric terms are used to describe the quantities of optical radiation in the wavelength range of visible radiation (generally assumed as the range from 380 nm to 780 nm). The relevant photometric terms are:

Photometric Term	Equivalent Radiometric Term	Symbol	Unit	Reference
Luminous power or Luminous flux	Radiant power or Radiant flux Φ_e	Φ_v	lm	Φ_v: IEC50 (845-01-25) lm: IEC50 (845-01-51)
Luminous intensity	Radiant intensity I_e	I_v	lm/sr = cd	I_v: IEC50 (845-01-31) cd: IEC50 (845-01-50)
Illuminance	Irradiance E_e	E_v	lm/m^2 = lx (Lux)	E_v: IEC50 (845-01-38) lx: IEC50 (845-01-52)
Luminous exitance	Radiant exitance M_e	M_v	lm/m^2	IEC50 (845-01-48)
Luminance	Radiance L_e	L_v	cd/m^2	IEC50 (845-01-35)

Table 2: Photometric Quantities and Units

Photometric units are derived from the radiometric units by weighting them with a wavelength dependent standardized human eye sensitivity V(λ) - function, the so-called CIE-standard photometric observer. There are different functions for photopic vision (V(λ)) and scotopic vision (V'(λ)).

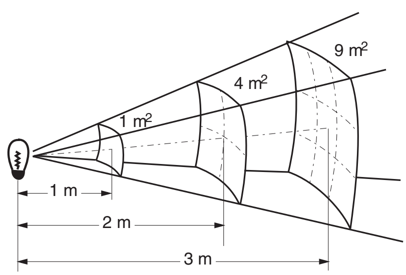
In the following is shown, how the luminous flux is derived from the radiant power and its spectral distribution. The equivalent other photometric terms can be derived from the radiometric terms in the same way.

Relation between distance r, irradiance (illuminance) E_e (E_v) and intensity I_e (I_v)

The relation between intensity of a source and the resulting irradiance in the distance r is given by the basic square root rule law.

An emitted intensity I_e generates in a distance r the irradiance $E_e = I_e/r^2$.

This relationship is not valid under near field conditions and should be used not below a distance d smaller than 5 times the emitter source diameter.



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Using a single radiation point source, one gets the following relation between the parameter E_e, Φ_e, r:

$$E_e = \frac{d\Phi_e}{dA}\left[\frac{W}{m^2}\right]$$

use

$$I_e = \frac{d\Phi}{dA}\ ,\ \Omega = \frac{A}{r^2}$$ and get

$$E_e = \frac{d\Phi_e}{dA} = I_e\frac{d\Omega}{dA} = \frac{I_e}{r^2}\left[\frac{W}{m^2}\right]$$

Examples

1. Calculate the irradiance with given intensity and distance r:

Transceivers with specified intensity of I_e = 100 mW/sr will generate in a distance of 1m an irradiance of $E_e = 100/1^2 = 100$ mW/m^2. In a distance of 10 m the irradiance would be $E_e = 100/10^2 = 1$ mW/m^2.

2. Calculate the range of a system with given intensity and irradiance threshold.

When the receiver is specified with a sensitivity threshold irradiance E_e = 20 mW/m^2, the transmitter with an intensity I_e = 120 mW/sr the resulting range can be calculated as

$$r = \sqrt{\frac{I_e}{E_e}} = \sqrt{\frac{120}{20}} = \sqrt{6} = 2,45m$$

Labeling

Vishay Semiconductor Standard Bar-Code Labels

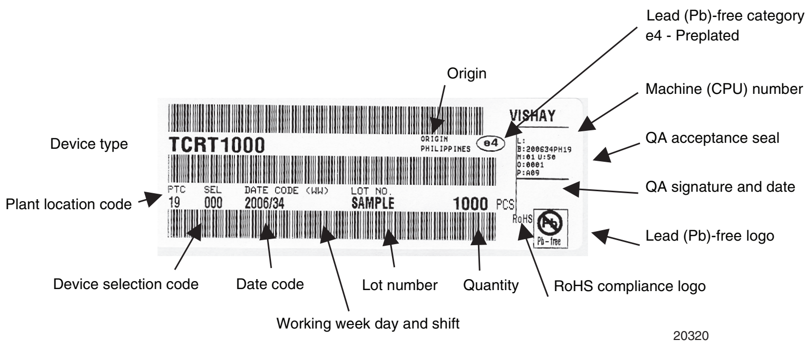
Standard bar code labels for finished goods

The standard bar code labels are product labels and used for identification of goods. The finished goods are packed in final packing area. The standard packing units are labeled with standard bar code (3-of-9 bar code (code 39) conforming MIL-STD-1189) before transported as finished goods to warehouses. The labels are on each packing unit with Vishay Semiconductor GmbH specific data. The content of the label is show in the following table and figure 1.
In future a change from 1D to 2D barcodes can be expected. That one will look like as shown in figure 2.

The following logos are used inside the bar code label which are shown in figure 3.

The following lead (Pb)-free categories (see figure 1 to figure 3) are meant to describe the lead (Pb)-free 2nd level interconnect terminal finish/material of components and/or the solder used in board assembly.

e1	SnAgCu (shall not be included in category 2)
e2	Sn alloys with no Bi or Zn excluding SnAgCu
e3	Sn
e4	Precious metal (e.g. Ag, Au, NiPd, NiPdAu) (no Sn)
e5	SnZn, SnZnx (no Bi)
e6	contains Bi
e7	low temperature solder (≤ 150 °C) containing Indium (no Bi)
e0, e8, e9	symbol are unassigned



Remark: Multi - Date Codes would be marked in the QA field of this label on top of the lead

Figure 1. Barcode label, detailed description

Figure 2. 2D barcode label (according the Barcode Standard for 2D Label PDF 417) for a lead (Pb)-free device, equivalent to that shown in figure 11.

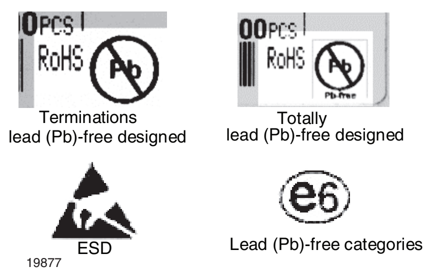


Figure 3. Logos inside the label

Soldering Instructions

Molding Material and Moisture Sensitivity

The molding material used by Vishay to manufacture optoelectronic components makes them uniquely different from standard integrated circuits. With the exception of Optocouplers and Solid State Relays, all of Vishay's optoelectronics components require light to pass in or out. Visible LEDs and infrared emitters transmit light, infrared receivers and photo detectors receive light, and optical sensors and IrDA transceivers transmit and receive light. For these products, epoxy is used as the encapsulant or packaging material. Visible LEDs and some infrared emitters and detectors use a clear epoxy while the remaining products include a visible light filtering dye to allow only infrared light to pass. In all cases, no resin or filler is added to the epoxy since it would block light. On the other hand, standard ICs, Optocouplers, and Solid State Relays typically use a mixture of 30 % epoxy and 70 % filler, mostly silica sand. This mixture results in more uniform mechanical properties; harder, lower coefficient of thermal expansion, high thermal conductivity, higher glass transition temperature and less sensitivity to moisture.

Without this filler, optoelectronic components are very sensitive to moisture. At room temperature, unfilled epoxy's moisture saturation value is approximately ten times greater than filled molding compound. Any possible void, for example delamination or a bubble, will quickly fill with moisture. Even the whole package can absorb a great deal of moisture. Vishay takes special precautions prior to shipping these products to ensure that they are free of moisture. Parts are baked prior to packaging. Then, the reels or tubes are sealed into moisture barrier bags containing desiccant and a humidity indicator card. As long as the parts are stored in the sealed bags, no problems will result when the parts are removed for soldering. The amount of moisture absorbed by these products is determined by the exposure time to humid air. As soon as the bag is opened, the parts should be assembled (soldered) within 72 hours given a temperature less than 30 °C and a relative humidity less than 60 %. If not, they should be stored in a dry place which is purged with a dry gas like nitrogen or baked according to the sticker on the reel.

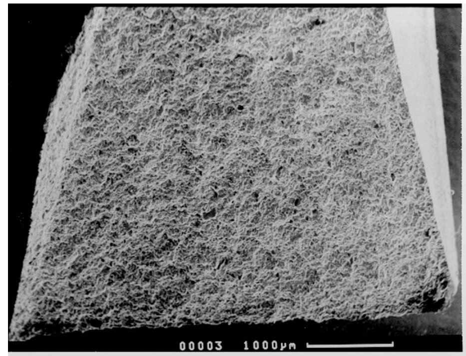


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Figure 1. IC molding compound (30 % resin)

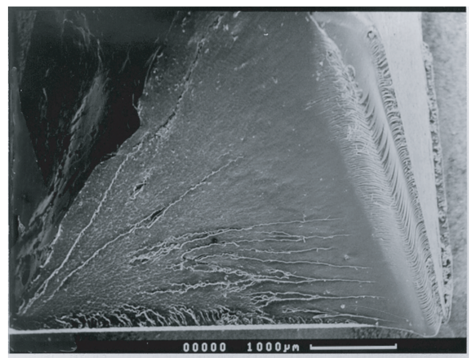

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Figure 2. Clear molding compound (100 % resin)

Again, with the exception of Optocouplers and Solid State Relays, Vishay's optoelectronic components have a moisture sensitivity level (MSL) of 3 or 4 per the JEDEC standards J-STD-020 and JESD22-A113. The environmental conditions above correlate to MSL 4.

Reflow Soldering

Reflow soldering is used to assemble surface mount components. Because optoelectronic components are more sensitive to thermal stress than most other components, the optoelectronic component should dictate the optimum soldering conditions. There are two different soldering profiles currently used: Ramp-Soak-Spike (RSS) and, as the use of convection ovens becomes more common, Ramp-To-Spike (RTS). The RSS soldering profile consists of three distinct phases.

- Pre-heating or Soak Phase where all parts should come to roughly the same temperature
- Soldering
- Cool down which should be done rather quickly to yield a fine grain solder joint

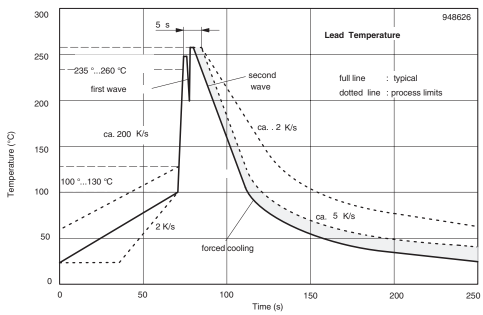
For RTS profiles, the low thermal conductivity of optoelectronic components requires that the ramp-up rate should be lower than for standard components. The optoelectronic component needs extra time to come to thermal equilibrium with the PCB and to have the internal stress thermally relieved.

Refer to the datasheets of each surface mount sensor for the appropriate reflow profile.

Wave Soldering

Wave soldering is commonly used to assemble leaded components. In wave soldering, one or more continuously replenished waves of molten solder are generated while the substrates to be soldered are moved in one direction across the crest of the wave. Again temperature and time play a critical role in successful assembly. The maximum temperature for a single or first wave is 235 °C and for a second wave is 260 °C. Total exposure time should be less than 5 seconds.

Vishay's recommended wave solder profile is shown in Figure 5.



Manual or Hand Soldering

Manual soldering is not recommended as a production process. As a standard lab process, the key is to reduce exposure time and temperature. Unless the bag was just opened, parts should be baked per the MSL 4 conditions. The iron temperature must be less than 260 °C. Exposure time per lead should be less than 5 seconds. The iron should be at least 2 mm from the package. The leads of the device should be stress free, in other words, the pins should not be spread during soldering.

Eye Safety of Diode Emitters

Since 1993, the International Electrotechnical Committee (IEC) and the European Committee for Electrotechnical Standardization (CENELEC, officially recognized as the European Standards Organization in its field by the Commission in Directive 83/189/EEC) have included Diode Emitters[1] such as IREDs[2] and LEDs[3] in the laser safety standard. LEDs and lasers are technologically similar. However, the different radiance of LEDs compared to lasers was not taken into account. This resulted in LEDs being incorrectly assessed concerning eye safety. In the 1997 edition of the standard EN 60825-1 (and the IEC equivalent IEC 60825-1) the basic assessment errors were corrected.

The standard was further revised in January 2001. Amendment 2 was added (IEC60825-1 Amd. 2 Ed. 1.0) and is available at www.iec.ch. Based on the parallel voting process, this standard is also effective as a CENELEC document, EN60825-1 Amendment 2. Amendment 2 allows for a large increase in exposure limits, especially for the extended sources such as conventional LEDs and IREDs. The standard describes the Maximum Possible Exposure (MPE) and the Accessible Emission Levels (AEL) for the human eye and skin. The safe emission level is dependent on exposure time, wavelength, virtual source size and other parameters. For extended sources like LEDs, the apparent or virtual source size is the most important parameter in assessing risk and shall be specified in the component manufacturer's data sheet. Given the revised exposure limits, under normal operating conditions the MPE and AEL values are difficult to exceed when using conventional LEDs. Also, recognizing the low risk emissions of these sources, Amendment 2 eliminated the single fault condition for standard LEDs.

Recent studies in the United States support these revisions; finding that eye damage can not be caused by even the brightest of currently available LEDs. Worldwide, no eye damage by LEDs has ever been reported. Still, Diode Emitters efficiency is increasing. Especially at the shorter wavelengths, a risk due to blue light effects, called blue light hazard, may occur and is to be considered.
By definition, Laser Class 1 devices are safe under all reasonably foreseeable conditions.

All of Vishay's Reflective and Transmissive Sensors are rated as Class 1 devices if operated within specified limits of data sheets. Then, radiant intensity will be within the eye safety limits.
Finally, if drive conditions are set higher than specifications, then thermal saturation of emitters will limit the output intensity.
Vishay's sensors, LEDs and IrDA transceivers are eye-safe.

For more information regarding LEDs see the ICNIRP (International Commission on Non-Ionizing Radiation Protection) statement "ICNIRP Statement on Light-Emitting diodes (LEDs) and Laser Diodes: Implications for Hazard Assessment"[4]).
In the United States the safety standard IEC60825-1, Amd. 2 is harmonized by the Food and Drug Administration's (FDA) Center for Devices and Radiological Health (CDRH): "Laser Products - Conformance with IEC60825-1, Am. 2 and IEC60601-2-22; Final Guidance for Industry and FDA (Laser Notice No. 50)[5]", issued July 26, 2001.

1) Diode Emitters: Semiconductor devices with diode characteristic emitting radiation such as LDs(laser diodes), IREDs or LEDs
2) IRED: Infrared Emitting Diode. It is common but not correct to use the term LED also for Infrared Emitting Diodes
3) LED: Light Emitting Diode, this term is used also for IR emitting diodes
4) Copyright© 2000 Health Physics Society. Copies are available from the Internet at: http://www.icnirp.org/documents/led.pdf
5) Copies are available from the Internet at: http://www.fda.gov/cdrh/comp/guidance/1346.html

Quality Information

Corporate Quality Policy

Our goal is to exceed the quality expectations of our customers. This commitment starts with top management and extends through the entire organization. It is achieved through innovation, technical excellence and continuous improvement.

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Figure 1. Vishay quality policy

VISHAY INTERTECHNOLOGY; INC.

ENVIRONMENTAL, HEALTH AND SAFETY POLICY

VISHAY INTERTECHNOLOGY, INC. is committed to conducting its worldwide operations in a socially responsible and ethical manner to protect the environment, and ensure the safety and health of our employees to conduct their daily activities in an environmentally responsible manner.

Protection of the Environment: Conduct our business operation in a manner that protects the environmental quality of the communities in which our facilities are located. Reduce risks involved with storage and use of hazardous materials. The company is also committed to continual improvement of its environmental performance.

Compliance with Environmental, Health and Safety Laws and Regulations:
Comply with all relevant environmental, health and safety laws and regulations in every location. Maintain a system that provides timely updates of regulatory change.
Cooperate fully with governmental agencies in meeting applicable requirements.

Energy, Resource Conservation and Pollution Control: Strive to minimize energy and material consumption in the design of products and processes, and in the operation of our facilities. Promote the recycling of materials, including hazardous wastes, whenever possible. Minimize the generation of hazardous and non-hazardous wastes at our facilities to prevent or eliminate pollution. Manage and dispose of wastes safely and responsibly.

Figure 2. Vishay Quality road map

Quality System

Quality Program

At the heart of the quality process is the Vishay worldwide quality program. This program, which has been in place since the early 90's, is specifically designed to meet rapidly increasing customer quality demands now and in the future.

Vishay Corporate Quality implements the Quality Policy and translates its requirements for use throughout the worldwide organization.

Vishay Quality has defined a roadmap with specific targets along the way. The major target is to achieve world-class excellence throughout Vishay worldwide by 2008.

VISHAY Corporate Quality

The Vishay Corporate Quality defines and implements the Vishay quality policy at a corporate level. It acts to harmonize the quality systems of the constituent divisions and to implement Total Quality Management throughout the company worldwide.

Vishay Zero Defect Program

- Exceeding quality expectations of our customers
- Commitment from top management through entire organization
- Newest and most effective procedures and tools
  - design, manufacturing and testing
  - management procedures (eg. SPC, TQM)
- Continuous decreasing numbers for AOQ and Failure Rate
- Detailed failure analysis using 8D methodology
- Continuous improvement of quality performance of parts and technology

Quality Goals and Methods

The goals are straightforward: Customer satisfaction through continuous improvement towards zero defects in every area of our operation. We are committed to meet our customers' requirements in terms of quality and service. In order to achieve this, we build excellence into our product from concept to delivery and beyond.

- Design-in Quality

Quality must be designed into products. Vishay uses optimized design rules based on statistical information. This is refined using electrical, thermal and mechanical simulation together with techniques such as FMEA, QFD and DOE.

- Built-in Quality

Quality is built into all Vishay products by using qualified materials, suppliers and processes. Fundamental to this is the use of SPC techniques by both Vishay and its suppliers. The use of these techniques, as well as tracking critical processes, reduces variability, optimizing the process with respect to the specification. The target is defect prevention and continuous improvement.

- Qualification

All new products are qualified before release by submitting them to a series of mechanical, electrical and environmental tests. The same procedure is used for new or changed processes or packages.

- Monitoring

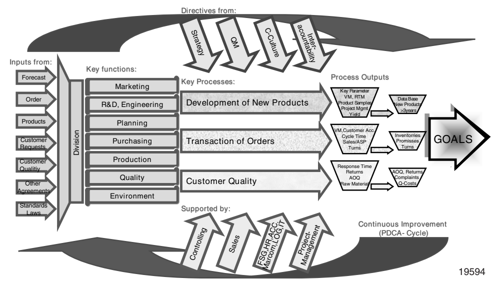
A selection of the same or similar tests used for qualification is also used to monitor the short- and long-term reliability of the product.

- SPC (Statistical Process Control)

SPC is an essential part of all Vishay process control. It has been established for many years and is used as a tool for the continuous improvement of processes by measuring, controlling and reducing variability.

- Vishay Quality System

All Vishay's facilities worldwide are approved to ISO 9000. In addition, depending on their activities, some Vishay companies are approved to recognized international and industry standards such as VDA 6.1 and QS 9000. Each subsidiary goal is to fulfill the particular requirements of customers. The Opto Divisions of Vishay Semiconductor GmbH are certified according to ISO 9001:2000, QS 9000 and ISO/TS 16949.



The procedures used are based upon these standards and laid down in an approved and controlled Quality Manual.

Total Quality Management

Total Quality Management is a management system combining the resources of all employees, customers and suppliers in order to achieve total customer satisfaction. The fundamental elements of this system are:

- Management commitment
- European Foundation for Quality Management (EFQM assessment methodology)
- Empowered Improvement Teams (EITs)
- Supplier development and partnership
- Quality tools
- Training
- Quality System

All Vishay employees from the senior management downwards are trained in understanding and using of TQM. Every employee plays its own part in the continuous improvement process which is fundamental to TQM and our corporate commitment to exceed customers' expectations in all areas including design, technology, manufacturing, human resources, marketing, and finance. Everyone is involved in fulfilling this goal. The management believes that this can only be achieved by employee empowerment.

The Vishay corporate core values

- Leadership by example
- Employee empowerment
- Continuous improvement
- Total customer satisfaction
- Business excellence

are the very essence of the Vishay Quality Movement process.

- Training

Vishay maintains that it can only realize its aims if the employees are well trained. It therefore invests heavily in courses to provide all employees with the knowledge they need to facilitate continuous improvement. A training profile has been established for all employees with emphasis being placed on Total Quality Leadership. Our long-term aim is to continuously improve our training so as to keep ahead of projected changes in business and technology.

- EFQM Assessment Methodology

From 1995, Vishay has started to introduce the EFQM (European Foundation for Quality Management) methodology for structuring its Total Quality Management approach. This methodology, similar to the Malcolm Baldrige process, consists in self-assessing the various Vishay divisions and facilities according to nine business criteria:

- Leadership
- People
- Policy & Strategy
- Partnership & Resources
- Processes
- People Results
- Customer Results
- Society Results
- Key Performance Results

(see figure 3)

The assessments are conducted on a yearly basis by trained and empowered, internal Vishay assessors. This permits the identification of keypriority improvement projects and the measurement of the progress accomplished.

The EFQM methodology helps Vishay to achieve world-class business excellence.

- Empowered Improvement Teams (EITs)

At Vishay we believe that every person in the company has a contribution to make in meeting our target of customer satisfaction. Management therefore empowers employees to higher and higher levels of motivation, thus achieving higher levels of effectiveness and productivity. Empowered improvement teams, which are both functional and cross functional, combine the varied talents from across the breadth of the company. By taking part in training, these teams are continually searching for ways to improve their jobs, achieving satisfaction for themselves, the company and most important of all the customer.

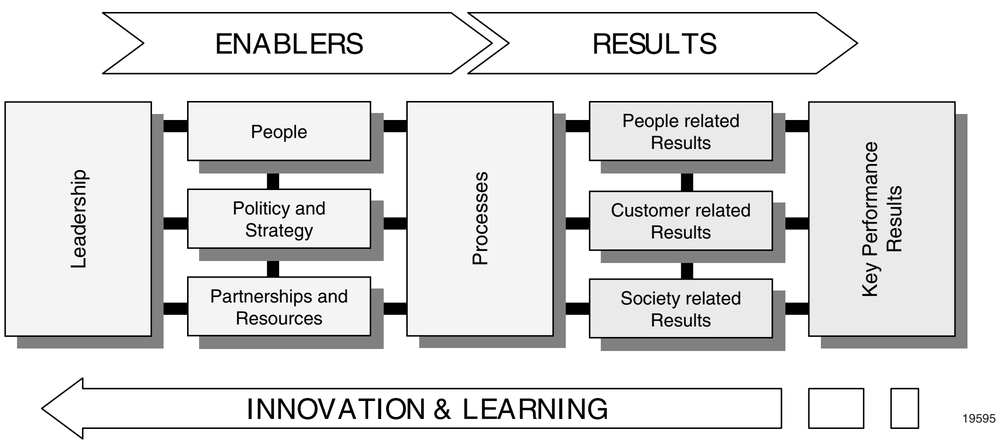


Figure 3. EFQM criteria for self-assessment

TQM Tools

As part of its search for excellence, Vishay employs many different techniques and tools. The most important of them are:

- Auditing

As well as third party auditing employed for approval by ISO 9000 and customers, Vishay carries out its own internal and external auditing. There is a common auditing procedure for suppliers and sub-contractors between the Vishay entities. This procedure is also used for inter-company auditing between the facilities within Vishay. It is based on the "Continuous Improvement" concept with heavy emphasis on the use of SPC and other statistical tools for the control and reduction of variability.

Internal audits are carried out on a routine basis. They include audits of satellite facilities (i.e., sales offices, warehousing etc.). Audits are also used widely to determine attitudes and expectations both within and outside the company.

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- Failure Mode and Effect Analysis (FMEA)

FMEA is a technique for analyzing the possible methods of failure and their effect upon the performance/ reliability of the product/process. Process FMEAs are performed for all processes. In addition, product FMEAs are performed on all critical or customer products.

- Design of Experiments (DOE)

There is a series of tools that may be used for the statistical design of experiments. It consists of a formalized procedure for optimizing and analyzing experiments in a controlled manner. Taguchi and factorial experiment design are included in this. They provide a major advantage in determining the most important input parameters, making the experiment more efficient and promoting common understanding among team members of the methods and principles used.

- Gauge Repeatability and Reproducibility (GR&R)

This technique is used to determine equipment's suitability for purpose. It is used to make certain that all equipment is capable of functioning to the required accuracy and repeatability. All new equipment is approved before use by this technique.

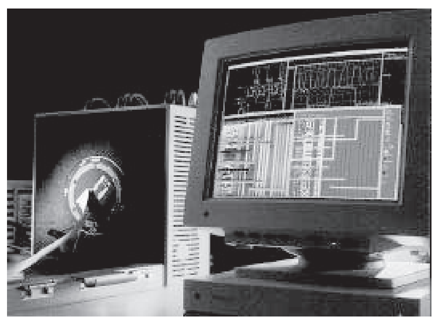
- Quality Function Deployment (QFD)

QFD is a method for translating customer requirements into recognizable requirements for Vishay's marketing, design, research, manufacturing and sales (including after-sales). QFD is a process, which brings together the life cycle of a product from its conception, through design, manufacture, distribution and use until it has served its expected life.

Quality Service

Vishay believes that quality of service is equally as important as the technical ability of its products to meet their required performance and reliability.

- Our objectives therefore include:
- On-time delivery
- Short response time to customers' requests
- Rapid and informed technical support
- Fast handling of complaints
- A partnership with our customers



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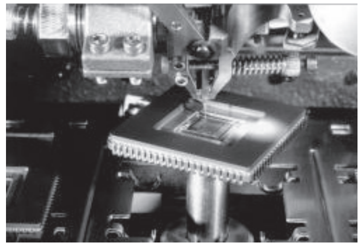
- Customer Complaints

Complaints fall mainly into two categories:

- Logistical
- Technical

Vishay has a procedure detailing the handling of complaints. Initially complaints are forwarded to the appropriate sales office where in-depth information describing the problem, using the Vishay **P**roduct **A**nalysis **R**equest and **R**eturn **F**orm (PARRF), is of considerable help in giving a fast and accurate response. If it is necessary to send back the product for logistical reasons, the Sales Office issues a Returned Material Authorization (RMA) number. On receipt of the goods in good condition, credit is automatically issued. If there is a technical reason for complaint, sample together with the **PARRF** is sent to the Sales Office for forwarding to the Failure Analysis Department of the supplying facility. The device's receipt will be acknowledged and a report issued on completion of the analysis. The cycle time this analysis has set targets and is constantly monitored in order to improve the response time. Failure analysis normally consists of electrical testing, functional testing, mechanical analysis (including X-ray), decapsulation, visual analysis and electrical probing. Other specialized techniques (i.e. LCD, thermal imaging, SEM, acoustic microscopy) may be used if necessary.

If the analysis uncovers a quality problem, Corrective Action Report (CAR) in 8D format will be issued. Any subsequent returns are handled with the RMA procedure.



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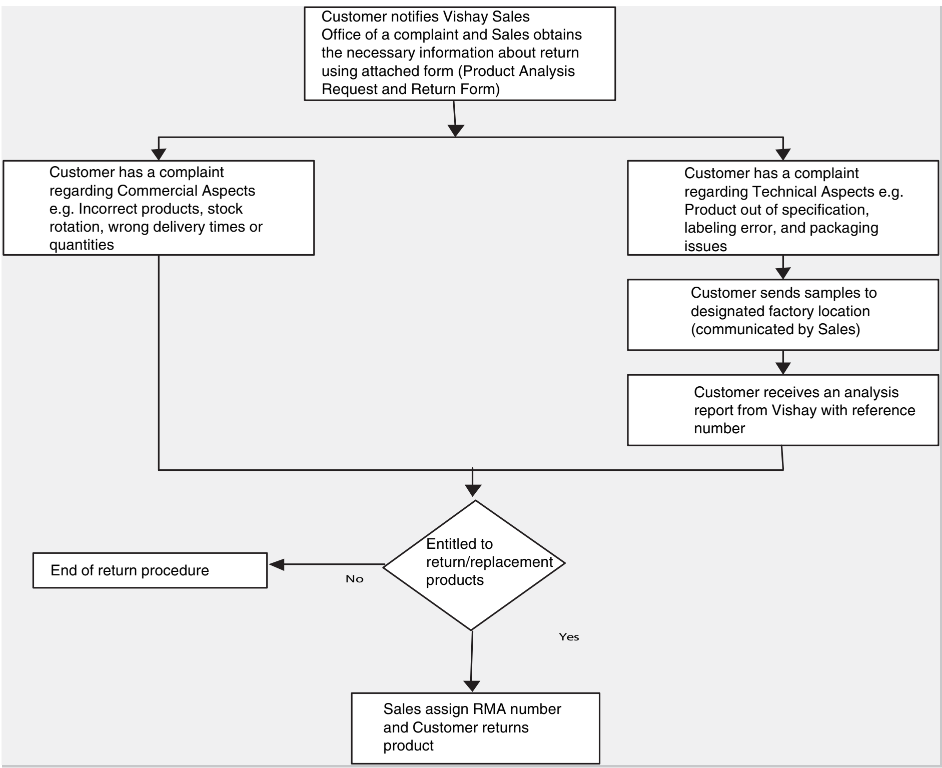

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Complaint and Return Procedure

Product Analysis Request and Return Form

Address Data

Customer:	Sales Ref.No:
Address:	Sales Office:
	Incoming Date:
Customer Ref.-No:	
Cust. Contact Person:	Sales Contact Person:
E-Mail:	E-Mail:
Phone:	Phone:
Fax:	Fax:

Product Analysis Request

Device:		Qty. for Analysis:
Date Code:	Plant Code:	Failure Rate:

Type of Complaint (pls. specify) — Failure description

- Electr. ☐
- Mechan. ☐
- Others ☐

Point of Failure:

Incoming ☐	Qualification ☐
Assembly ☐	Reliability ☐
Field Failure ☐	Others ☐

Stress Conditions before Failure:
(Temp / %HR / Voltage / Others)

Application:
(please specify)

Remarks / Other Data:
(please specify)

Return Request

Device:	RMA-No. : (mandatory)
Date Code	
Inv. No.:	
Commercial Return ☐	
Technical Return ☐	
CAR-No. of 8D - Report:	

QM Vishay *Issue: 02.10.2000* 19596

Product **A**nalysis **R**equest and **R**eturn **F**orm (PARRF)

Company Address Company Phone Number VISHAY Company Name 8D Report	CAR Number: Page: 1 Report Date:

Complete following for all applicable items:

Date Opened:		Originator		Company Specific Information	
Vishay Location:		Vishay Part No.:		Plant code:	
Customer:		Date Code:		Lot Serial No.:	
Customer Location:		Device Type:		Lot size:	
Customer Ref. Code:		Value:		Sample Qty:	
Customer Part No.:		Tolerance:		Failure rate:	
Customer P.O. No.:		RMA Number:			
Analysis Code:		Package Type:			

8D APPROACH – Disciplines 1, 2, and 4 below must be completed for ALL requests.

DISCIPLINE 1: ESTABLISH TEAMS

DISCIPLINE 2: DESCRIBE PROBLEM

DISCIPLINE 3: CONTAINMENT ACTIONS

DISCIPLINE 4: ROOT CAUSE/RESULTS

If VALID, ALL Disciplines must be completed.

DISCIPLINE 5: CORRECTIVE ACTIONS

DISCIPLINE 6: IMPLEMENT CORRECTIVE ACTIONS

DISCIPLINE 7: PREVENT RECURRENCE

DISCIPLINE 8: CONGRATULATE TEAM

Revised by:		Rev.:		Date:	
Approved by:		Date:		Date Closed:	

Form # CQA004 Rev B 04/26/02

MANUFACTURER OF THE WORLD'S BROADEST LINE OF DISCRETE SEMICONDUCTORS AND PASSIVE COMPONENTS

Confidential Information

19598

Vishay 8D form

- Change Notification

All product and process changes are controlled and released via ECN (Engineering Change Notification). This requires the approval of the relevant departments. In the case of a major change, the change is forwarded to customers via Sales/ Marketing before implementation. Where specific agreements are in place, the change will not be implemented unless approved by the customer.

- Ship-to-Stock/Ship-to-Line (STS/STL)

Many customers now require devices to be shipped direct to stock or to the production line by omitting any goods inwards inspection. Vishay welcomes such agreements as part of its customer partnership program, which promises an open approach in every aspect of its business. A product will only be supplied as STS or STL if there is a valid agreement in place between the two companies. Such an agreement details the quality level targets agreed upon between the companies and the methods to be used in case of problems.

Quality and Reliability

Assurance Program

Though both quality and reliability are designed into all Vishay products, three basic programs must assure them:

- Average Outgoing Quality (AOQ) –
  100 % testing is followed by sample testing to measure the defect level of the shipped product. This defect level (AOQ) is measured in ppm (parts per million).
- Reliability qualification program –
  to assure that the design, process or change is reliable.
- Reliability monitoring program –
  to measure and assure that there is no decrease in the reliability of the product.

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AOQ Program

Before leaving the factory, all products are sampled after 100% testing to ensure that they meet a minimum quality level and to measure the level of defects. The results are accumulated and expressed in ppm (parts per million). They are the measure of the average number of potentially failed parts in deliveries over a period of time. The sample size used is determined by AQL or LTPD tables depending upon the product. No rejects are allowed in the sample.

The AOQ value is calculated monthly using the method defined in standard JEDEC 16:

$$AOQ = p \cdot LAR \cdot 10^6 (ppm)$$

where:

$$p = \frac{\text{number of devices rejected}}{\text{total number of devices tested}}$$

LAR = lot acceptance rate:

$$LAR = 1 - \frac{\text{number of lots rejected}}{\text{total number of lots tested}}$$

The AOQ values are recorded separately with regard to electrical and mechanical (visual) rejects by product type and package.

The actual qualification procedure depends on which of these (or combinations of these) are to be qualified. Normally there are three categories of qualification in order of degree of qualification and testing required:

- New technology or process (this includes a new design on a new process)

- New product or re-designed product using a qualified process
  New package including piece-part or material change
  New manufacturing location
- Minor change of process, assembly or package

Accelerated testing is normally used in order to produce results fast. The stress level employed depends upon the failure mode investigated. The stress test is set so that the level used gives the maximum acceleration without introducing any new or untypical failure mode.

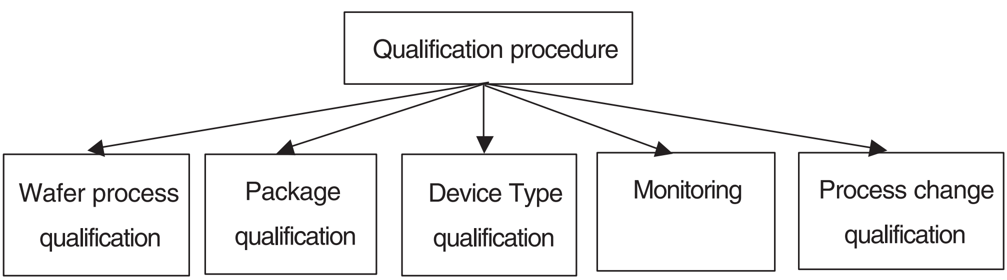
The tests used consist of a set of the following:

- High temperature life test (static)
- High temperature life test (dynamic)
- HTRB (High Temperature Reverse Bias)
- Humidity 85/85 (with or without bias)
- HAST (Highly Accelerated Stress Test)
- Temperature cycling
- High-temperature storage
- Low-temperature storage
- Marking permanency
- Lead integrity
- Solderability
- Resistance to solder heat
- Mechanical shock (not plastic packages)
- Vibration (not plastic packages)
- ESD characterization

SMD devices only are subjected to preconditioning to simulate board assembly techniques using the methods defined in standard JSTD 020A before being subjected to stresses.

Normally, the endpoint tests are related to the data sheet or to specified parameters. Additionally, they may include:

- Destructive physical analysis
- X-ray
- Delamination testing using scanning acoustic microscope
- Thermal imaging
- Thermal and electrical resistance analysis



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Example of the QualPack

Reliability Monitoring & Wear Out

The monitoring program consists of short-term monitoring to provide fast feedback on a regular basis in case of a reduction in reliability and to measure the Early-life Failure Rate (EFR). At the same time, Long-term monitoring is used to determinate the Long-term steady-state Failure Rate (LFR). The tests used are a subset from those used for qualification and consist of:

- Life tests
- Humidity tests
- Temperature-cycling tests
- Solderability tests
- Resistance-to-solder-heat test

The actual tests used depend on the product tested.

Depending on the assembly volume a yearly monitoring and wear out test plan is created.

Wear Out data are very important in Opto electronic device. Out of that data degradation curves can be made. These curves show the long time behavior of the different devices.

Some typical curves are attached in this report.

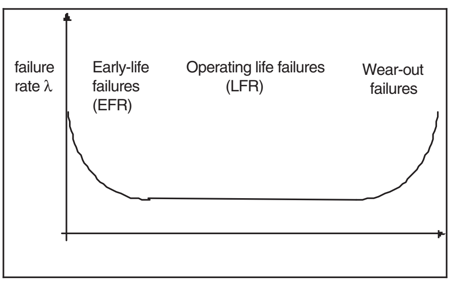

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Figure 4. Bathtub curve

Reliability Principles

Reliability is the probability of survival as a function of time and stress, and is usually expressed in terms of FITs (failures in 109 device hours). It is expressed as:

$$F(t) + R(t) = 1 \quad \text{or} \quad R(t) = 1 - F(t)$$

where:

R(t) = probability of survival

F(t) = probability of failure

$F(t) = 1\text{-}e^{-l^{t}}$

where

l = instantaneous failure rate

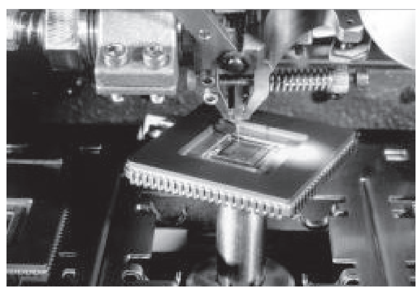
t = time

thus,

$$R(t) = e^{-l^{t}}$$

The lifetime distribution or hazard rate curve is shown on figure 4. This curve is also known as the 'bath-tub curve' because of its shape. There are three basic sections:

- Early-life failures (infant mortality)
- Operating-life failures (random failures)
- Wear-out failures



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The failure rate (l) during the constant (random) failure period is determined from life-test data. The failure rate is calculated from the formula:

$$\lambda = \frac{r}{\Sigma(Fi \cdot ti) + (N \cdot t)} = \frac{r}{C}$$

where

λ = failure rate (hours-1)
r = number of observed failures
f_i = failure number
t_i = time to defect
N = good sample size
t = entire operating time
C = number of Components X hours

The result is expressed in either

a) % per 1000 component hours by multiplying by 10^5

or in

b) FITs by multiplying by 10^9 (1 FIT = 10^{-9} hours $^{-1}$)

Example 1: Determination of failure rate λ 500 devices were operated over a period of 2000 hours (t) with:
1 failure (f1) after 1000 hours (t1) and
1 failure (f2) after 1500 hours (t2).
The failure rate of the given example can be calculated as follows:

$$\lambda = \frac{2}{(1 \cdot 1000h) + (1 \cdot 1500h) + (498 \cdot 2000h)}$$

$$\lambda = 2 \cdot 10^{-6} \text{hours}^{-1}$$

That means that this sample has an average failure rate of **0.2 %/1000 hours or 2000 FIT**

Observed failure rates as measured above are for the specific lot of devices tested. If the predicted failure rate for the total population is required, statistical confidence factors have to be applied.

The confidence factors can be obtained from "chi square" (χ^2) charts. Normally, these charts show the value of (χ^2/2) rather than χ^2. The failure rate is calculated by dividing the χ^2/2 factor by the number of component hours.

$$\lambda_{pop} = \frac{(\chi^2/2)}{C}$$

The values for χ^2/2 are given in table 1

Number of Failures	Confidence Level	
	60 %	90 %
0	0.92	2.31
1	2.02	3.89
2	3.08	5.30
3	4.17	6.70
4	5.24	8.00
5	6.25	9.25
6	7.27	10.55

Table 1: χ^2/2 chart

Example 2: The failure rate of the population
Using example 1 with a failure rate of 2000 FIT and 2 failures:
χ^2/2 at 60% confidence is 3.08

$$\lambda_{pop} = \frac{3.08}{9.985 \cdot 10^5} = 3085 \text{ FIT}$$

This means that the failure rate of the population will not exceed 3085 FIT with a probability of 60 %

- Accelerated Stress Testing

In order to be able to assure long operating life with a reasonable confidence, Vishay carries out accelerated testing on all its products. The normal accelerating factor is the temperature of operation. Most failure mechanisms of semiconductors are dependent upon temperature. This temperature dependence is best described by the Arrhenius equation.

$$\lambda_{T2} = \lambda_{T1} \times e^{\left[\frac{E_A}{k} \times \left(\frac{1}{T1} - \frac{1}{T2}\right)\right]}$$

where

k = Boltzmann's constant 8.63 x 10^{-5} eV/K
E_A = Activation energy (eV)
T_1 = Operation temperature (K)
T_2 = Stress temperature (K)
λ_{T1} = Operation failure rate
λ_{T2} = Stress-test failure rate

Using this equation, it is possible from the stress test results to predict what would happen in use at the normal temperature of operation.

- Activation Energy

Provided the stress testing does not introduce a failure mode, which would not occur in practice, this method gives an acceptable method for predicting reliability using short test periods compared to the life of the device. It is necessary to know the activation energy of the failure mode occurring during the accelerated testing. This can be determined by experiment. In practice, it is unusual to find a failure or if there is, it is a random failure mode. For this reason an average activation energy is normally used for this calculation. Though activation energies can vary between 0.3 and 2.2 eV, under the conditions of use, activation energies of between 0.6 and 0.9 eV are used depending upon the technology.

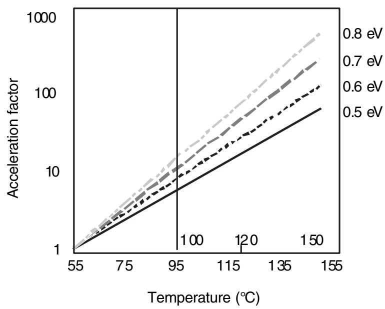

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Figure 5. Acceleration factor for different activation energies normalized to T = 55 °C

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Activation Energies for common failure mechanisms

The activation energies for some of the major semiconductor failure mechanisms are given in the table below. These are estimates taken from published literature.

Failure mechanism	Activation Energy
Mechanical wire shorts	0.3 – 0.4
Diffusion and bulk defects	0.3 – 0.4
Oxide defects	0.3 – 0.4
Top-to-bottom metal short	0.5
Electro migration	0.4 – 1.2
Electrolytic corrosion	0.8 – 1.0
Gold-aluminum intermetallics	0.8 – 2.0
Gold-aluminum bond degradation	1.0 – 2.2
Ionic contamination	1.02
Alloy pitting	1.77

Table 2: Activation energies for common failure mechanism

Failure rates are quoted at an operating temperature of 55 °C and 60 % confidence using an activation energy (E_A) of 0.8 eV for optoelectronic devices.

Example 3: Conversion to 55 °C

In Example 2, the life test was out at 150 °C so to transform to an operating temperature of 55 °C.

T1 = 273 + 55 = 328K

T1 = 273 + 150 = 423K

Acceleration factor =

$$\frac{\lambda_{(T2)}}{\lambda_{(T1)}} = \frac{\lambda_{(423K)}}{\lambda_{(328K)}} = 258$$

$$\lambda_{(328K)} = \frac{\lambda_{(423K)}}{258} = \frac{3080}{258}$$

= 12 FIT

(at 55 °C with a confidence of 60 %)

This figure can be re-calculated for any operating/junction temperature using this method.

- EFR (Early Life Failure Rate)

This is defined as the proportion of failures, which will occur during the warranty period of the system for which they were designed. In order to standardize this period, Vishay uses 1000 operation hours as the reference period. This is the figure also used by the automotive industry; it equates to one year in the life of an automobile. In order to estimate this figure, Vishay normally operates a sample of devices for 48 or 168 hours under the accelerated conditions detailed above. The Arrhenius law is then used as before to calculate the failure rate at 55 °C with a confidence level of 60 %. This figure is multiplied by 1000 to give the failures in 1000 hours and by 10^6 to give a failure in ppm. All EFR figures are quoted in ppm (parts per million).

- Climatic Tests Models

Temperature cycling failure rate The inverse power law is used to model fatigue failures of materials that are subjected to thermal cycling. For the purpose of accelerated testing, this model relationship is called Coffin-Manson relationship, and can be expressed as follows:

$$A_F = \left(\frac{\Delta T_{stress}}{\Delta T_{use}}\right)^M$$

where:

A_F = Acceleration factor

ΔT_{use} = temp. range under normal operation

ΔT_{stress} = temp. range under stress operation

M = constant characteristic of the failure mechanism.

Failure mechanism	Coffin–Manson exponent M
Al wire bond failure	3.5
Intermetallic bond fracture	4.0
Au wire bond heel crack	5.1
Chip-out bond failure	7.1

Table 3: Coffin - Manson exponent M

For instance:

$$\Delta T_{use} = 15\ °C/\ 60\ °C = 45\ °C$$

$$\Delta T_{stress} = -25\ °C/\ 60\ °C = 125\ °C$$

$$A_F = \left(\frac{125\ °C}{45\ °C}\right)^3 \approx 21$$

Relative Humidity failure rate

Moisture effect modeling is based upon the Howard-Pecht-Peck model using the acceleration factor of the equation shown below:

$$A_F = \left(\frac{RH_{stress}}{RH_{use}}\right)^C \cdot e^{\left[\frac{E_A}{k}\left(\frac{1}{T_{use}} - \frac{1}{T_{stress}}\right)\right]}$$

where:

RH_{stress} = relative humidity during test

RH_{use} = relative humidity during operation

T_{stress} = temperature during test

T_{use} = temperature during operation

E_A = activation energy

k = Boltzmann constant

C = Material constant

For instance:

RH_{stress} = 85 % RH_{use} = 92 %

T_{stress} = 358 K T_{use} = 313 K

$$A_F = \left(\frac{85\ \%\ RH}{92\ \%\ RH}\right)^3 \cdot e^{\left[\frac{0,8}{8,617 Þ 10^{-5}}\left(\frac{1}{313} - \frac{1}{358}\right)\right]}$$

$$A_F \approx 33$$

This example shows how to transform test conditions into environmental or into another test conditions. This equation is applicable for devices subjected to temperature humidity bias (THB) testing.

Using these acceleration factors the useful lifetime can be calculated. Applying the acceleration factor once more, useful lifetime for the moisture effect model for parts subjected to THB can be estimated by the following equation:

$$\text{Useful life}_{\text{Years}} = \frac{A_F \cdot \text{test hours}}{\text{hours per year}}$$

with:

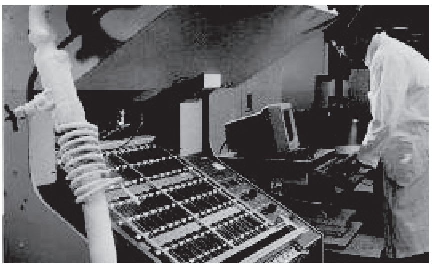
Test hours = 1000

hours per year = 8760

$A_F \approx 118$ (40 °C/60 % RH)

$$\text{Useful life}_{\text{Years}} = \frac{118 \cdot 1000}{8760} \approx 13.5 \text{ years}$$

This means that operation in 40 °C / 60 % RH environment is good for around 13 years, calculated out of the 85 °C/ 85 % RH 1000h humidity stress test.



18370

Wafer Level Reliability Testing

Due to the increasing demand for complex devices with reduced geometry, Vishay is committed to enhancing and improving process and product quality through the use of Wafer Level Testing (WLT). Through the use of custom-designed and standard test devices and structures, the on-going design as well as the process quality and reliability are monitored both at the wafer and package level. When implemented in the manufacturing process, they provide a rapid means of monitoring metal integrity and parameter stability.

The main tests are:

- Electro-migration

Commonly known as SWEAT (Standard Wafer- Level Electro-migration Test), this test is used as a metallization process quality monitor.

- Mobile ion instability

Special sensitive transistors are used together with built-in heaters to measure the effect of the movement of mobile ions at the interface region.

Handling for Quality

- Electrostatic Discharge (ESD) Precautions

Electrostatic discharge is defined as the high voltage, which is generated when two dissimilar materials move in contact with one another. This may be by rubbing (i.e. walking on a carpet) or by hot air or gas passing over an insulated object. Sometimes, ESD is easily detectable as when a person is discharged to ground (shock).

Electronic devices may be irreversibly damaged when subjected to this discharge. They can also be damaged if they are charged to a high voltage and then discharged to ground.

Damage due to ESD may occur at any point in the process of manufacture and use of the device. ESD is a particular problem if the humidity is low (< 40 %) which is very common in non-humidified but air-conditioned buildings. ESD is not just generated by the human body but can also occur with un-grounded machinery.

ESD may cause a device to fail immediately or damage a device so that it will fail later. Whether this happens or not, usually depends on the energy available in the ESD pulse.

All ESD-sensitive Vishay products are protected by means of

- Protection structures on chip
- ESD protection measures during handling and shipping

Vishay has laid down procedures, which detail the methods to be used for protection against ESD. These measures meet or exceed those of EN61340-5-1 or MIL-STD-1686, the standards for ESD-protective and preventative measures.

These include the use of:

- Grounded wrist straps
- Grounded benches
- Conductive floors
- Protective clothing
- Controlled humidity

It also lays down the methods for routinely checking these and other items such as the grounding of machines.

A semiconductor device is only completely protected when enclosed in a «Faraday Cage». This is a completely closed conductive container (i.e., sealed conductive bag or box).

Most packaging material (i.e. tubes) used for semiconductors is now manufactured from antistatic material or anti-static-coated material. This does not mean that the devices are completely protected from ESD, only that the packing will not generate ESD. Devices are completely protected only when surrounded on all sides by a conductive package.

It should also be remembered that devices can equally as easily be damaged by discharge from a high voltage to ground as vice-versa.

Testing for ESD resistance is part of the qualification procedure. The methods used are detailed in MIL-STD-883 Method 3015.7 (Human Body Model) and EOS/ESD-S5.1-1993 (Machine Model) specification.

- Latch-up

The latch-up effect is a state in which a low impedance path results and persists following an input, output or the latch-up effect is a state in which a low impedance path supply over voltage that triggers a parasitic Thyristor.

Due to this effect an over current occurs in the IC, which can destroy the IC. At least the supply voltage of the IC must be cut off to get back the IC in a defined state.

Normally, the latch-up test is carried out just at CMOS ICs. This CMOS latch-up test is according to the JEDEC 17 standard. For Bipolar ICs, there is no standard available so far.

- Soldering

All products are tested to ascertain their ability to withstand the industry standard soldering conditions after storage. In general, these conditions are as follows.

- Hand soldering: 260 °C, 2 mm from the device body for 10 s.
- Wave soldering: Double-wave soldering according to CECC 00802 maximum 2 x total restricted to 3 soldering operations
- Reflow soldering: convection soldering according to CECC 00802 with a maximum temperature of 260 °C, maximum 2 x with the total restricted to 3 soldering operations, IR soldering to CECC 00802 with a maximum temperature of 245 °C maximum 2 x with the total restricted to 3 soldering operations

Note: certain components may have limitations due to their construction.

- Dry pack

When being stored, certain types of device packages can absorb moisture, which is released during the soldering operations, thus causing damage to the device. The so-called «popcorn» effect is such an example. To prevent this, Surface Mount Devices (SMD) are evaluated during qualification, using a test consisting of moisture followed by soldering simulation (pre-conditioning) and then subjected to various stress tests. In table Number 3 - Moisture Sensitivity Levels – the six different levels, the floor life conditions as well as the soak requirements belonging to these levels are described. Any device, which is found to deteriorate under these conditions, is packaged in «dry pack».

The dry-packed devices are packed generally according to EIA-583 «Packaging Material Standards for Moisture Sensitive Items», IPC-SM-786 «Recommended Procedures for Handling of Moisture Sensitive Plastic IC Packages».

The following are general recommendations:

- Shelf life in the packaging at < 40 °C and 90 % RH is 12 months.
- After opening, the devices should be handled according to the specifications mentioned on the dry-pack label.
- If the exposure or storage time is exceeded, the devices should be baked:
- Low-temperature baking - 192 hours at 40 °C and 5 % RH
- High-temperature backing - 24 hours at 125 °C.

	Floor	Life	Soak Requirements			
Level	Conditions	Time	Time (hours)			Conditions
1	≤ 30 °C / 90 % RH	Unlimited	168			85 °C / 85 % RH
2	≤ 30 °C / 60 % RH	1 year	168			85 °C / 60 % RH
2a	≤ 30 °C / 60 % RH	4 Weeks	696hrs			30 °C / 60 % RH
			X	Y	Z	
3	≤ 30 °C / 60 % RH	168 h.	24	168	192	30 °C / 60 % RH
4	≤ 30 °C / 60 % RH	72 h.	24	72	96	30 °C / 60 % RH
5	≤ 30 °C / 60 % RH	24 / 48 h.	24	24 / 48	48 / 72	30 °C / 60 % RH
6	≤ 30 °C / 60 % RH	6 h.	0	6	6	30 °C / 60 % RH

Table 4: Moisture Sensitivity Levels

X = Default value of semiconductor manufacturer's exposure time (MET) between bake and bag plus the maximum time allowed out of the bag at the distributor's facility. The actual times may be used rather than the default times, but they must be used if they exceed the default times.

Y = Floor life of package after it is removed from dry pack bag (level 8 after completion of bake).

Z = Total soak time for evaluation (X + Y).

Note: There are two possible floor lives and soak times in Level 5. The correct floor life will be determined by the manufacturer and will be noted on the dry pack bag label per JEP 113.«Symbol and Labels for Moisture Sensitive Devices».

Reliability & Statistics Glossary

Definitions

Accelerated Life Test: A life test under conditions that are more severe than usual operating conditions. It is helpful, but not necessary, that a relationship between test severity and the probability distribution of life be ascertainable.

Acceleration Factor: Notation: f(t) = the time transformation from more severe test conditions to the usual conditions. The acceleration factor is f(t)/t. The differential acceleration factor is df(t)/dt.

Acceptance number: The largest numbers of defects that can occur in an acceptance sampling plan and still have the lot accepted.

Acceptance Sampling Plan: An accept/reject test the purpose of which is to accept or reject a lot of items or material based on random samples from the lot.

Assessment: A critical appraisal including qualitative judgements about an item, such as importance of analysis results, design criticality, and failure effect.

Attribute (Inspection By): A term used to designate a method of measurement whereby units are examined by noting the presence (or absence) of some characteristic or attribute in each of the units in the group under consideration and by counting how many units do (or do not) possess it. Inspection by attributes can be two kinds: either the unit of product is classified simply as defective or not defective or the number of defects in the unit of product is counted with respect to a given requirement or set of requirements.

Attribute Testing: Testing to evaluate whether or not an item possesses a specified attribute.

Auger Electron Spectrometer: An instrument, that identifies elements on the surface of a sample. It excites the area of interest with an electron beam and observes the resultant emitted Auger electrons.

These electrons have the specific characteristics of the near surface elements. It is usually used to identify very thin films, often surface contaminants.

Availability (Operational Readiness): The probability that at any point in time the system is either operating satisfactorily or ready to be placed in operation on demand when used under stated conditions.

Average Outgoing Quality (AOQ): The average quality of outgoing product after 100 % inspection of rejected lot, with replacement by good units of all defective units found in inspection.

Bathtub Curve: A plot of failure rate of an item (whether repairable or not) vs. time. The failure rate initially decreases, then stays reasonably constant, then begins to rise rather rapidly. It has the shape of bathtub. Not all items have this behavior.

Bias: (1) The difference between the expected value of an estimator and the value of the true parameter; (2) Applied voltage.

Burn-in: The initial operation of an item to stabilize its characteristics and to minimize infant mortality in the field.

Confidence Interval: The interval within which it is asserted that the parameters of a probability distribution lies.

Confidence Level:
Equals $1 - \alpha$ where α = the risk (%).

Corrective Action: A documented design, process, procedure, or materials change to correct the true cause of a failure. Part replacement with a like item does not constitute appropriate corrective action. Rather, the action should make it impossible for that failure to happen again.

Cumulative Distribution Function (CDF): The probability that the random variable takes on any value less than or equal to a value x, e.g.
$F(x) = CDF(x) = Pr(x \le X)$.

Defect: A deviation of an item from some ideal state. The ideal state usually is given in a formal specification.

Degradation: A gradual deterioration in performance as a function of time.

Derating: The intentional reduction of stress/strength ratio in the application of an item, usually for the purpose of reducing the occurrence of stress-related failures.

Duty Cycle: A specified operating time of an item, followed by a specified time of no operation.

Early Failure Period: That period of life, after final assembly, in which failures occur at an initially high rate because of the presence of defective parts and workmanship. This definition applies to the first part of the bathtub curve for failure rate (infant mortality).

EDX Spectrometer: Generally used with a scanning electron microscope (SEM) to provide elemental analysis of X-rays generated on the region being hit by the primary electron beam.

Effectiveness: The capability of the system or device to perform its function.

EOS – Electrical Overstress: The electrical stressing of electronic components beyond specifications. May be caused by ESD.

ESD – Electrostatic Discharge: The transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field. Many electronic components are sensitive to ESD and will be degraded or fail.

Expected Value: A statistical term. If x is a random variable and F (x) it its CDF, the E (x) = xdF (x), where the integration is over all x. For continuous variables with a pfd, this reduces to E (x) = ∫x pfd (x) dx. For discrete random variables with a pfd, this reduces to E (x) = $\Sigma x_n p(x_n)$ where the sum is over all n.

Exponential Distribution: A 1-parameter distribution ($\lambda > 0$, $t \leq 0$) with: pfd (t) = lexp ($-\lambda t$);
Cdf (t) 0 1 – exp ($-\lambda t$); Sf (t) = exp ($-\lambda t$) ;
failure rate = λ; mean time-to-failure = $1/\lambda$. This is the constant failure-rate-distribution.

Failure: The termination of the ability of an item to perform its required function.

Failure Analysis: The identification of the failure mode, the failure mechanism, and the cause (i.e., defective soldering, design weakness, contamination, assembly techniques, etc.). Often includes physical dissection.

Failure, Catastrophic: A sudden change in the operating characteristics of an item resulting in a complete loss of useful performance of the item.

Failure, Degradation: A failure that occurs as a result of a gradual or partial change in the operating characteristics of an item.

Failure, Initial: The first failure to occur in use.

Failure, Latent: A malfunction that occurs as a result of a previous exposure to a condition that did not result in an immediately detectable failure. Example: Latent ESD failure.

Failure Mechanism: The mechanical, chemical, or other process that results in a failure.

Failure Mode: The effect by which a failure is observed. Generally, describes the way the failure occurs and tells "how" with respect to operation.

Failure Rate: (A) The conditional probability density that the item will fail just after time t, given the item has not failed up to time t; (B) The number of failures of an item per unit measure of life (cycles, time, miles, events, etc.) as applicable for the item.

Failure, Wearout: Any failure for which time of occurrence is governed by rapidly increasing failure rate.

FIT: Failure Unit; (also, Failures In Time) Failures per 10^9 hours.

Functional Failure: A failure whereby a device does not perform its intended function when the inputs or controls are correct.

Gaussian Distribution: A 2-parameter distribution with:

$$\text{pfd}(x) = \frac{1}{\sigma\sqrt{2\pi}} \cdot e^{\frac{1}{2}\left(\frac{x-u}{\sigma}\right)^2}$$

Cdf (x) = guaf (x). SF (x) = gaufc (x). "Mean value of x" u, "standard deviation of x" = σ

Hazard Rate: Instantaneous failure rate.

Hypothesis, Null: A hypothesis stating that there is no difference between some characteristics of the parent populations of several different samples, i.e., that the samples came from similar populations.

Infant Mortality: Premature catastrophic failures occurring at a much greater rate than during the period of useful life prior to the onset of substantial wear out.

Inspection: The examination and testing of supplies and services (including when appropriate, raw materials, components, and intermediate assemblies) to determine whether they conform to specified requirements.

Inspection by Attributes: Inspection whereby either the unit of product or characteristics thereof is classified simply as defective or not defective or the number of defects in the unit of product is counted with respect to a given requirement.

Life Test: A test, usually of several items, made for the purpose of estimating some characteristic(s) of the probability distribution of life.

Lot: A group of units from a particular device type submitted at one time for inspection and / or testing.

Lot Reject Rate (LRR): The lot reject rate is the percentage of lots rejected form the lots evaluated.

Lot Tolerance Percent Defective (LTPD): The percent defective which is to be accepted a minimum or arbitrary fraction of the time, or that percent defective whose probability of rejection is designated by **b**.

Mean: (A) The arithmetic mean, the expected value; (B) As specifically modified and defined, e.g., harmonic mean (reciprocals), geometric mean (a product), logarithmic mean (logs).

Mean Life: R(t)dt; where R(t) = the reliability of the item; t = the interval over which the mean life is desired, usually the useful life (longevity).

Mean-Life-Between-Failures: The concept is the same as mean life except that it is for repaired items and is the mean up-time of the item. The formula is the same as for mean life except that R(t) is interpreted as the distribution of up-times. Mean-Time-

Between-Failures (MTBF): For a particular interval, the total functioning life of a population of an item divided by the total number of failures within the population during the measurement interval. The definition holds for time, cycles, miles, events, or other measure of life units.

Mean-Time-To-Failure (MTTF): See "Mean Life".

Mean-Time-To-Repair (MTTR): The total corrective maintenance time divided by the total number of corrective maintenance actions during a given period of time.

MTTR: = G(t)dt; where G(t) = Cdf of repair time;
t = maximum allowed repair time, i.e., item is treated as not repairable at this echelon and is discarded or sent to a higher echelon for repair.

Operating Characteristic (OC) Curve: A curve showing the relation between the probability of acceptance and either lot quality or process quality, whichever is applicable.

Part Per Million (PPM): PPM is arrived at by multiplying the percentage defective by 10,000.

Example: 0.1 % = 1,000 PPM.

Population: The totality of the set of items, units, measurements, etc., real or conceptual, that is under consideration.

Probability Distribution: A mathematical function with specific properties, which describes the probability that a random variable will take on a value or set of values. If the random variable is continuous and well behaved enough, there will be a pfd. If the random variable is discrete, there will be a pmf.

Qualification: The entire process by which products are obtained from manufacturers or distributors, examined and tested, and then identified on a Qualified Product List.

Quality: A property which refers to the tendency of an item to be made to specific specifications and/or the customer's express needs. See current publications by Juran, Deming, Crosby, et al.

Quality Assurance: A system of activities that provides assurance that the overall quality control job is being done effectively. The system involves a continuing evaluation of the adequacy and effectiveness of the overall quality control program with a view to having corrective measures initiated where necessary. For a specific product or service, this involves verifications, audits, and the evaluation of the quality factors that affect the specification, production inspection, and use of the product or service.

Quality Characteristics: Those properties of an item or process, which can be measured, reviewed, or observed and which are identified in the drawings, specifications, or contractual requirements. Reliability becomes a quality characteristic when so defined.

Quality Control (QC): The overall system of activities that provides a quality of product or service, which meets the needs of users; also, the use of such a system.

Random Samples: As commonly used in acceptance sampling theory, the process of selecting sample units in such a manner that all units under consideration have the same probability of being selected.

Reliability: The probability that a device will function without failure over a specified time period or amount of usage at stated conditions.

Reliability Growth: Reliability growth is the effort, the resource commitment, to improve design, purchasing, production, and inspection procedures to improve the reliability of a design.

Risk: α : The probability of rejecting the null hypothesis falsely.

Scanning Electron Microscope (SEM): An instrument which provides a visual image of the surface features of an item. It scans an electron beam over the surface of a sample while held in a vacuum and collects any of several resultant particles or energies. The SEM provides depth of field and resolution significantly exceeding light microscopy and may be used at magnifications exceeding 50,000 times.

Screening Test: A test or combination of tests intended to remove unsatisfactory items or those likely to exhibit early failures.

Significance: Results that show deviations between hypothesis and the observations used as a test of the hypothesis, greater than can be explained by random variation or chance alone, are called statistically significant.

Significance Level: The probability that, if the hypothesis under test were true, a sample test statistic would be as bad as or worse than the observed test statistic.

SPC: Statistical Process Control.

Storage Life (Shelf Life): The length of time an item can be stored under specified conditions and still meet specified requirements.

Stress: A general and ambiguous term used as an extension of its meaning in mechanics as that which could cause failure. It does not distinguish between those things which cause permanent damage (deterioration) and those things which are not (in the absence of failure).

Variance: The average of the squares of the deviations of individual measurements from their average. It is a measure of dispersion of a random variable or of data.

Wearout: The process of attribution which results in an increase of hazard rate with increasing age (cycles, time, miles, events, etc.) as applicable for the item.

Abbreviations

AQL	Acceptable Quality Level
CAR	Corrective Action Report / Request
DIP	Dual In-Line Package
ECAP	Electronic Circuit Analysis Program
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
EOS	Electrical Overstress
ESD	Electrostatic Discharge
FAR	Failure Analysis Report / Request
FIT	(Failure In Time) Failure Unit; Failures / 10^9 hours
FMEA	Failure Mode and Effects Analysis
FTA	Fault Tree Analysis
h (t)	Hazard Rate
LTPD	Lot Tolerance Percent Defective
MOS	Metal Oxide Semiconductor
MRB	Material Review Board
MTBF	Mean-Time-Between-Failures
MTTF	Mean-Time-To-Failure
MTTR	Mean-Time-To-Repair
PPM	Parts Per Million
PRST	Probability Ratio Sequential Test
QA	Quality Assurance
QC	Quality Control
QPL	Qualified Products List
RPM	Reliability Planning and Management
SCA	Sneak Circuit Analysis
SEM	Scanning Electron Microscope
TW	Wearout Time
Z (t)	Hazard Rate
λ	Failure Rate (Lambda)

Document Number: 81463
Rev. 1.0, 12-Sep-06

VISHAY INTERTECHNOLOGY, INC.
ENVIRONMENTAL HEALTH AND SAFETY POLICY
1 JUNE 2006

VISHAY INTERTECHNOLOGY, INC. is committed to conducting its worldwide operations in a socially responsible and ethical manner to protect the environment, and ensure the safety and health of our employees, customers, and surrounding communities. To accomplish this policy, the Company hereby establishes the following objectives to be adopted as standard policies by all our worldwide operations.

Safety and Health of our Employees: Provide a safe and healthy working environment for our employees and contractors working at our sites. Integrate safety, health, and environmental protection into our business activities. Educate and train employees and contractors to conduct their daily activities in an environmentally responsible and safe manner.

Protection of the Environment: Conduct our business operations in a manner that protects the environmental quality of the communities in which our facilities are located. Reduce risks involved with storage and use of hazardous materials. The Company is also committed to continual improvement of its environmental performance.

Compliance with Environmental Health and Safety Laws and Regulations: Comply with all relevant environmental health and safety laws and regulations in every location. Maintain a system that provides timely updates of regulatory change. Develop a product stewardship program that ensures that changes in EHS requirements are reflected in Company products and processes. Cooperate fully with governmental agencies in meeting applicable requirements. Facilities are also expected to comply with other EHS requirements adopted by the Company.

Energy, Resource Conservation and Pollution Control: Strive to minimize energy and material consumption in the design of products and processes, and in the operation of our facilities. Promote the recycling of materials, including hazardous wastes, whenever possible. Minimize the generation of hazardous and non-hazardous wastes at our facilities to prevent or eliminate pollution. Manage and dispose of wastes safely and responsibly.

Communications: Promote sound environmental health and safety principles and practices by encouraging open communication with employees, governmental agencies, suppliers, contractors, customers and industry groups.

Audits: Conduct periodic audits of the Company's compliance with laws, regulations and Vishay's Environmental Health and Safety Policies and other requirements to which the Company subscribes. Promptly implement plans for any required corrective actions. Provide overall assessment of Company's Environmental Health and Safety management systems.

To ensure that this policy is continuously implemented by the Company's worldwide operations, the Vice President, Environmental Health and Safety, will provide regular reports to top management on the environmental health and safety status at each location. The Vice President, Environmental Health and Safety reports to the Environmental Committee appointed by the Board of Directors.

Dr. Gerald Paul
President and Chief Executive Officer
Vishay Intertechnology, Inc.

Reflective Sensors

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Optical Sensors - Reflective

Vishay is a leading manufacturer of optical sensors. These sensors integrate an infrared emitter and photo detector in a single package. The most common types of optical sensors are transmissive and reflective sensors.

Transmissive sensors, also called interrupter sensors, incorporate an infrared emitter and photo detector that face each other as shown in Figure 1. When an object is located between the emitter and detector in the sensing path, it interrupts or breaks the optical beam of the emitter. The amount of light energy reaching the detector is reduced. This change in light energy or photo current is used to affect an event in the application.

Reflective sensors incorporate an infrared emitter and photo detector adjacent to each other as shown in Figure 2. When an object is in the sensing area, the emitted light is reflected back towards the photo detector, the amount of light energy reaching the detector increases. This change in light energy or photo current is similarly used an input signal in the application.

This application note describes the proper use of Vishay's reflective sensors. It describes several factors that must be considered when using a reflective sensor. Vishay manufactures many reflective sensors in leaded and surface mount packages. One is just right for your application. Should you have any design questions, Vishay's Application Engineers are ready to assist you.

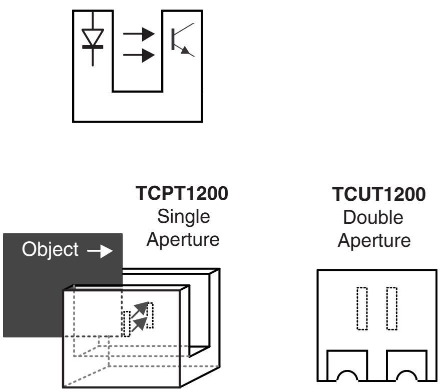


Figure 1.

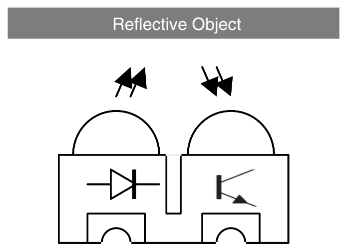


Figure 2.

Datasheet Parameter Values

The datasheets of each sensor include the absolute maximum ratings, and electrical and optical characteristics. The absolute maximum ratings of the emitter, detector and the sensor combined are provided. Maximum values for parameters like reverse and forward voltage, collector current, power dissipation, and ambient and storage temperatures are defined. The reflective sensors must be operated within these limits. In practice, applications should be designed so that there is large margin between the operating conditions and the absolute maximum ratings. The electrical and optical characteristics indicate the performance of the sensor under specific operating conditions. Generally, the minimum and/or maximum values are provided. These values are guaranteed and are tested during the manufacture of the sensor. Typical values, while sometimes provided, should only be used as a guide in the design process. They may or may not be tested during the manufacturing process and are not guaranteed. Table 2 at the end of this note provides the symbol, parameter and definition of data found in reflective sensor datasheets.

Reflective Materials

The reflective sensor parameter values are measured using a metal mirror or an industry-standard reference surface called the Kodak neutral card also known as the gray or white card. The white side of the card has a reflection factor of 90 % while the gray side has a factor of 18 %. To learn more about the Kodak neutral card refer to Kodak's publication No. Q-13, CAT 1527654. Table 1 shows the relative values of measured reflection of a number of materials. They were measured with the TCRT1000, with a forward current of 20 mA, at distance where the collector current was highest and with a wavelength of 950 nm. While the TCRT1000 was used, these values apply to all reflective sensors under the same operating conditions. These measurements have important practical use when designing a reflective sensor application. The reflection of surfaces in the infrared range can vary significantly from that in the visible range.

Table 1. Relative collector current (or coupling factor) of thereflex sensors for reflection on various materials. Reference is the white side of the Kodak neutral card. The sensor is positioned perpendicular to the surface. The wavelength is 950 nm

Kodak neutral card	
White side (reference medium)	100 %
Gray side	20 %
Paper	
Typewriting paper	94 %
Drawing card, white (Schoeller Durex)	100 %
Card, light gray	67 %
Envelope (beige)	100 %
Packing card (light brown)	84 %
Newspaper paper	97 %
Pergament paper	30 - 42 %
Black on white typewriting paper	
Drawing ink (Higgins, Pelikan, Rotring)	4 - 6 %
Foil ink (Rotring)	50 %
Fiber-tip pen (Edding 400)	10 %
Fiber-tip pen, black (Stabilo)	76 %
Photocopy	7 %
Plotter pen	
HP fiber-tip pen (0.3 mm)	84 %
Black 24 needle printer (EPSON LQ-500)	28 %
Ink (Pelikan)	100 %
Pencil, HB	26 %

Plastics, glass	
White PVC	90 %
Gray PVC	11 %
Blue, green, yellow, red PVC	40 - 80 %
White polyethylene	90 %
White polystyrene	120 %
Gray partinax	9 %
Fiber glass board material	
Without copper coating	12 - 19 %
With copper coating on the reverse side	30 %
Glass, 1 mm thick	9 %
Plexiglass, 1 mm thick	10%
Metals	
Aluminum, bright	110 %
Aluminum, black anodized	60 %
Cast aluminum, matt	45 %
Copper, matt (not oxidized)	110 %
Brass, bright	160 %
Gold plating, matt	150 %
Textiles	
White cotton	110 %
Black velvet	1.5 %

Operating Range and Peak Operating Distance

The phototransistor collector current is also dependent on the distance of the reflecting material from the sensor. Figure 3 shows the relative collector current versus the distance of the material from the sensor for the TCRT1000. This curve is included in each reflective sensor datasheet. The data was recorded using the Kodak neutral card's 90 % diffuse reflecting surface. The distance was measured from the surface of the sensor. The emitter current, I_F, was held constant during the measurement. This curve is called the working diagram. The working diagram of all reflective sensors shows a maximum collector current at a certain distance. For greater distances, collector current decreases. The working diagram is an important input to the reflective sensor circuit design. Choosing an operating distance at or near the sensors maximum collector current will provide greater design flexibility.

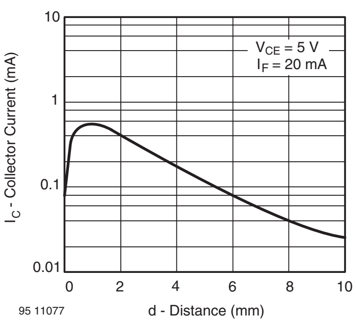


Figure 3. Collector Current vs. Distance

Switching Distance and Resolution

As an object moves over a reflective sensor the radiation reflected back to the detector changes gradually. For example, imagine a surface with an area high reflectivity and low reflectivity. As it moves over the sensor, Figure 4, the emitted radiation is reflected back to the detector. As the low-reflective surface moves into the sensing area of the detector, the collector current begins to drop-off. As this motion continues, a point is reached where the low-reflective surface completely envelops the detectors field of view. The edge of a sheet of paper, a black line on a shaft or the gaps in an encoding wheel will all see this gradual rise and fall in collector current. The switching distance, X_d, is the displacement relating to the width from 90 % I_{c1} to 10 % of I_{c2}. This distance is predominantly dependent on the mechanical and optical design of the sensor, and the distance to the reflecting surface. The resolution of the sensor is the capability to recognize a change in reflectivity. If the width of a black line on a spinning shaft is less than X_d, then the change in collector current may not be large enough and recognition by the sensor uncertain. The shorter the switching distance, the higher the sensors resolution.

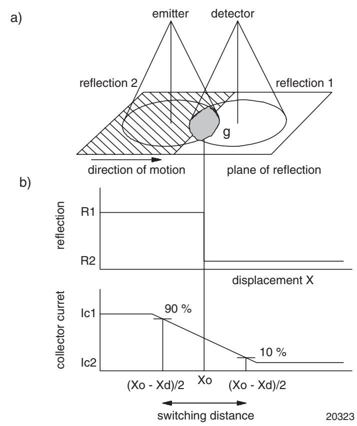


Figure 4. Abrupt reflection change with associated I_C curve

Cross Talk

The lowest light current that can be processed as a useful signal in the sensor's detector determines the weakest useable reflection and defines the sensitivity of the reflective sensor. This light current is determined by two parameters: cross talk and dark current. Whether the reflective sensor is lead-frame or PCB based, some of the emitted light will be internally reflected or channeled within the package to the detector. This is called optical cross talk. It is measured by operating the sensor without a reflective medium. While Vishay's sensors are designed to minimize crosstalk, the current must be considered when defining the circuit. The maximum cross talk current for each of Vishay's reflective sensors is specified in data sheets.

Reflection of the emitted light off of windows or surfaces surrounding the sensor is another source of cross talk to account for in the application design. In many applications this ambient crosstalk will be much higher than internal crosstalk of the sensor components and will determine signal to noise ratio or operating distance.

Dark Current

When a phototransistor is placed in the dark, or zero ambient illumination, and a voltage is applied from collector to emitter, a certain amount of current will flow. This current is called the dark current. It consists of the leakage current of the collector-base junction multiplied by the DC current gain of the transistor. The presence of this current prevents the phototransistor from being considered completely "off" or being an ideal "open switch". In datasheets, the dark current is described as being the maximum collector current permitted to flow at a given collector-emitter voltage. The dark current is a function of this voltage and temperature, Figure 5. Vishay phototransistors are tested at a V_{CE} applied voltage of 20 V. All reflective sensors which use a phototransistor specify a maximum dark current of 200 nA at 25 °C (typical 1 nA).

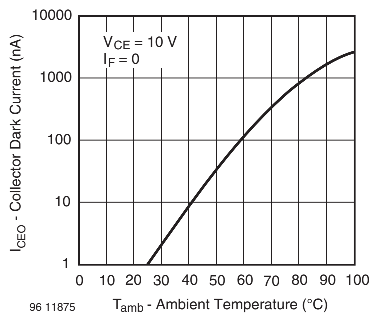


Figure 5. Collector Dark Current vs. Ambient Temperature

Temperature

Photo transistors and infrared emitting diodes are temperature dependent. As temperature increases, the light and dark current increases while emitter output decreases. An increase in the light current of the phototransistor is off-set by a decrease in the output of the emitter, Figure 6 and 7. Consequently, the change in the output of reflective sensors due to temperature change is comparatively small at less than 10 % from - 10 °C to + 70 °C, Figure 8. Because of this, it is not recommended to try to compensate for changes in temperature in the design of reflective sensor circuit.

Temperature also plays an important role in determining the emitter forward current in the application. As an example, for the TCRT1000, the maximum forward current at an ambient temperature of 25 °C is 50 mA. As shown in Figure 9, the forward current must be reduced according to changes in the ambient temperature. If the ambient temperature is 60 °C, the maximum current is 25 mA. This means a current exceeding 25 mA must not flow into the emitter. In practice, the actual current should include a large safety margin and the lowest possible current should be used.

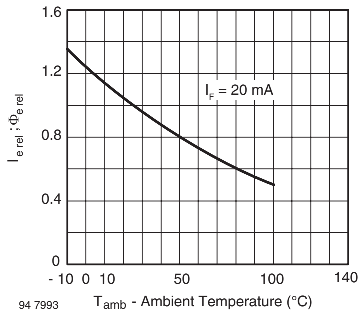


Figure 6. Rel. Radiant Intensity/Power vs. Ambient Temperature

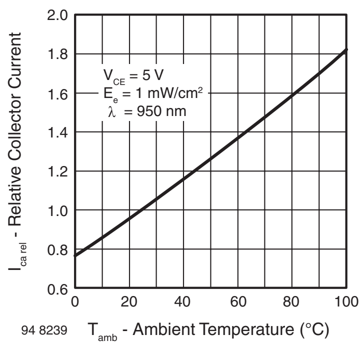


Figure 7. Rel. Collector Current vs. Ambient Temperature

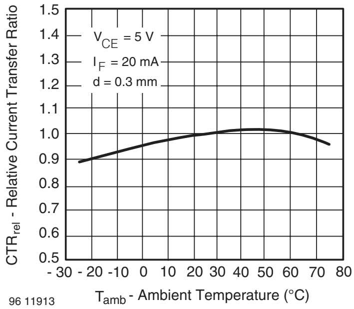


Figure 8. Rel. Current Transfer Ratio vs. Ambient Temperature

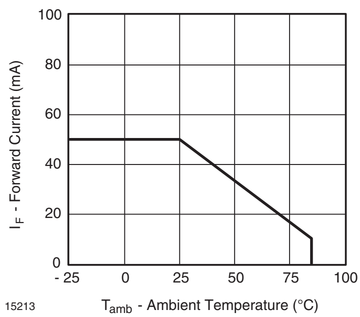


Figure 9. Forward Current vs. Ambient Temperature

Ambient Light

Ambient light can impair the sensitivity of the reflective sensor. Steady light falling directly on the detector reduces the sensor's sensitivity. Strong light can saturate the phototransistor and, in this condition, the sensor is blind. Varying ambient light results in incorrect signals and non-existent reflection changes. In applications where the ambient light source is known and relatively weak, in most cases it is enough to estimate the expected power of this light on the detector and to consider the result when defining the circuit. However, in many applications, it is difficult to precisely determine the ambient light and its effects. Ambient light is not only a problem when falling on the detector but can also be a problem when falling on the reflective surface. If the ambient light affects the object's and background's reflective factor in the same way, the ambient light effect can be ignored for low intensities. On the other hand, the object and background's reflective factor can differ. The background may reflect ambient light much more than the object. In this case, ambient light may reduce the contrast between the object and the background and the object may not be detected. Conversely, the sensor may detect a non-targeted feature because it reflects the ambient light much more than the surroundings.
Therefore, the influence of ambient light must be minimized by using optical filters, inspired mechanical design and, if necessary, AC operation. Vishay's reflective sensors are molded from epoxy that blocks visible light. Still, a large portion of sunlight is in the infrared. Locate or house the sensor so it is recessed to eliminate direct light. Pulsed operation can be helpful in some applications. AC operation is the most effective protection against ambient light.

Emitter Intensity

Emitter intensity depends largely on the forward current, I_F, optical efficiency of the lens and an internal reflector cup if included. The absolute maximum forward current of Vishay's TCRT1000, TCRT5000 and CNY70 is 50 mA, while the TCND5000 is 100 mA at an ambient temperature of 25 °C. The lower limit of the forward current of the emitter of any reflective sensor must be 5 mA minimum. If the forward current is too low, the optical output of the emitter will not be stable. A current limiting resistor is required. Without it, the current of the diode is theoretically limitless and the diode will burn out. The value of the current limiting resistor is calculated using the formula

$$R_L = (V_{CC} - V_F) / I_F$$

where the forward voltage of the emitter, V_F, typically 1.25 V, is subtracted from the supply voltage, V_{CC}, and divided by the forward current. Again, design in safety margin between actual operating conditions and the absolute maximum ratings. The external current limiting resistor defines the light intensity of the emitter. Driving the emitter with higher forward current to obtain larger reflected signal strength is not always be the best solution.

Response Time and Load Resistor

The speed of response of a phototransistor is dominated by the capacitance of the collector-base junction and the value of the load resistance. A phototransistor takes a certain amount of time to respond to sudden changes in light intensity. The response time is usually expressed by the rise time and fall time of the detector. As long as the light source driving the phototransistor is not intense enough to cause optical saturation, characterized by the storage of excess amounts of charge carriers in the base region, rise time equals fall time. If optical saturation occurs, fall time can become much larger than rise time. The selection of the load resistor, R_L, will also determine the amount of current-to-voltage conversion in the circuit. Reducing the value of R_L will result in a faster response time at the expense of a smaller voltage signal.

Degradation

End-users purchasing a reflective sensor want an accurate estimate of how long the sensor will last. Many will have minimum life requirements. Unlike most traditional light sources, infrared emitting diodes do not fail catastrophically. Instead, the light output degrades over time, Figure 10. Therefore the useful life of a reflective sensor can be defined by the time when it fails to provide sufficient light for the intended application. Infrared and visible light emitting diode life is often quoted to be 100000 hours but this is based on the average life span of a single, 5 mm epoxy encapsulated emitter. Vishay's reflective sensors also have a single emitter that is epoxy encapsulated. With some similarity, average life span can be considered comparable. As a rule-of-thumb, plan for 30 % degradation of the emitter over the life time of the sensor.

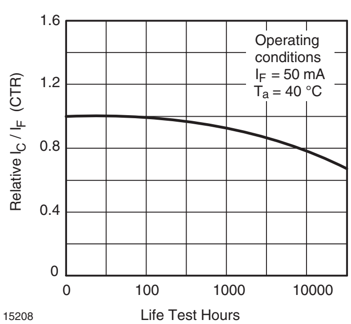


Figure 10.

The three main causes of degradation are:

- A loss of efficiency caused by mechanical stress deforming the crystal structure
- A loss of optical coupling caused by delamination between epoxy and chip
- A loss of efficiency caused by thermal stress on the crystal structure

The rate of degradation or aging is affected by:

- Chip technology: GaAs and GaAlAs Double Hetero (DH) technologies result in lower rates, while GaAlAs and GaAlAs/GaAs technologies result in higher rates of aging
- Package technology: metal can packaging technologies result in lower rates, and epoxy packaging technologies result in higher rates of aging
- Chip size: The smaller the chip, the higher the current density. A higher current density results in faster aging

There are a number of ways to minimize emitter degradation or aging. First, minimize the junction temperature. As long as the junction temperature, T_J, is kept below 100 °C, heating of the pn-junction will cause no significant degradation. To reduce junction temperature, minimize the forward current and the ambient temperature. Second, in applications where there is temperature cycling, keep the forward current for the corresponding temperature well below that shown in Figure 9. This is especially important since degradation due to mechanical stress and delamination is potentially greater in epoxy-based sensors. Third, in applications where response time is not critical, pulse the emitter instead of constant current operation. Reflective sensor datasheets include a curve showing Total Power Dissipation versus Ambient Temperature. Use this curve as a guide to minimize degradation.

Vishay features state-of-the-art chip technologies and high quality standards in the assembly process resulting in low degradation rate of our sensor components.

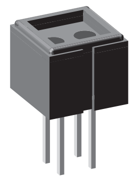
Table 2.

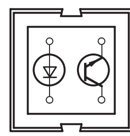
Parameter	Symbol	Definition
V_R	Reverse voltage	The maximum permissible applied voltage to the anode of the LED such that the current flows in the reverse direction
I_F	Forward Current	The direct or continuous current flowing in the forward direction of a diode, from the anode to the cathode
I_{FSM}	Forward surge current	The maximum permissible surge or pulse current allowed for a specified temperature and period in the forward direction
P_V	Power dissipation	The maximum power that is consumed by the collector junction of a phototransistor
TJ	Junction temperature	The spatial mean value of the collector junction temperature during operation
V_{CEO}	Collector emitter voltage	The positive voltage applied to the collector of a phototransistor with the emitter at a reference potential and open base
V_{ECO}	Emitter collector voltage	The positive voltage applied to the emitter of a phototransistor with the collector at a reference potential and open base
I_C	Collector current	The current that flows to the collector junction of a phototransistor
T_{amb}	Ambient Temperature	The maximum permissible ambient temperature
T_{stg}	Storage Temperature	The maximum permissible storage temperature without an applied voltage
V_F	Forward voltage	The voltage drop across the diode in the forward direction when a specified forward current is applied
I_{CEO}	Collector dark current	The current leakage of the phototransistor when a specified bias voltage is applied so that the polarity of the collector is positive and that of the emitter is negative on condition that the illumination of the sensor is zero
I_{CX}	Cross talk current	The output current measured at a specified voltage and forward current when there is no reflective medium
V_{CEsat}	Collector emitter saturation voltage	The continuous voltage between the collector and emitter when the detector is in its "ON" state as measured with the Kodak neutral test card, white side
t_r	Rise time	Amount of time it takes the output voltage to go from 10 % of the lower specified value to 90 % of the upper specified value
t_f	Fall time	The time required for the output voltage to go from 90 % of the upper specified value to 10 % of the lower specified value

Reflective Optical Sensor with Transistor Output

Description

The CNY70 is a reflective sensor that includes an infrared emitter and phototransistor in a leaded package which blocks visible light.





19158

Features

- Package type: Leaded
- Detector type: Phototransistor
- Dimensions: L 7 mm x W 7 mm x H 6 mm
- Peak operating distance: < 0.5 mm
- Operating range: 0 mm to 4.5 mm
- Typical output current under test: I_C = 1 mA
- Daylight blocking filter
- Emitter wavelength: 950 nm
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC
- Minimum order quantity 4000 pcs in tubes, 80 pcs/tube

Pb Pb-free

e4

Applications

Optoelectronic scanning and switching devices i.e., index sensing, coded disk scanning etc. (optoelectronic encoder assemblies).

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Value	Unit
Total power dissipation	$T_{amb} \leq 25$ °C	P_{tot}	200	mW
Ambient temperature range		T_{amb}	- 40 to + 85	°C
Storage temperature range		T_{stg}	- 40 to + 100	°C
Soldering temperature	Distance to case 2 mm, $t \leq 5$ s	T_{sd}	260	°C

Input (Emitter)

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_R	5	V
Forward current		I_F	50	mA
Forward surge current	$t_p \leq 10$ µs	I_{FSM}	3	A
Power dissipation	$T_{amb} \leq 25$°C	P_V	100	mW
Junction temperature		T_j	100	°C

Output (Detector)

Parameter	Test condition	Symbol	Value	Unit
Collector emitter voltage		V_{CEO}	32	V
Emitter collector voltage		V_{ECO}	7	V
Collector current		I_C	50	mA
Power dissipation	$T_{amb} \leq 25$ °C	P_V	100	mW
Junction temperature		T_j	100	°C

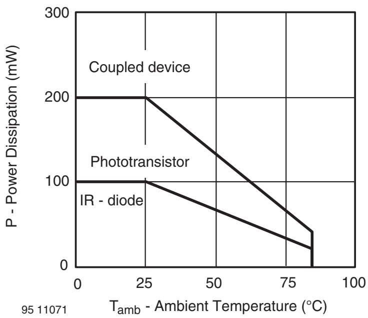


Figure 1. Power Dissipation Limit vs. Ambient Temperature

Electrical Characteristics

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector current	V_{CE} = 5 V, I_F = 20 mA, d = 0.3 mm (figure 2)	I_C [1)	0.3	1.0		mA
Cross talk current	V_{CE} = 5 V, I_F = 20 mA (figure 1)	I_{CX} [2)			600	nA
Collector emitter saturation voltage	I_F = 20 mA, I_C = 0.1 mA, d = 0.3 mm (figure 2)	V_{CEsat} [1)			0.3	V

[1)] Measured with the "Kodak neutral test card", white side with 90 % diffuse reflectance

[2)] Measured without reflecting medium

Input (Emitter)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	I_F = 50 mA	V_F		1.25	1.6	V
Radiant intensity	I_F = 50 mA, t_P = 20 ms	I_e			7.5	mW/sr
Peak wavelength	I_F = 100 mA	λ_P	940			nm
Virtual source diameter	Method: 63 % encircled energy	Ø		1.2		mm

Output (Detector)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector emitter voltage	I_C = 1 mA	V_{CEO}	32			V
Emitter collector voltage	I_E = 100 μA	V_{ECO}	5			V
Collector dark current	V_{CE} = 20 V, I_f = 0, E = 0	I_{CEO}			200	nA

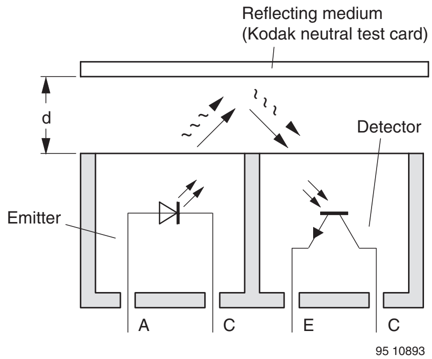


Figure 2. Test Condition

Typical Characteristics

T_{amb} = 25 °C unless otherwise specified

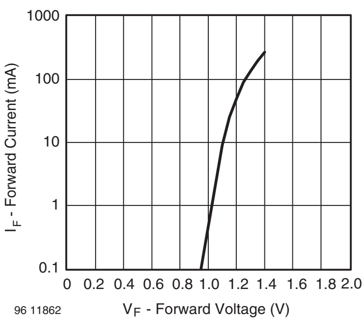


Figure 3. Forward Current vs. Forward Voltage

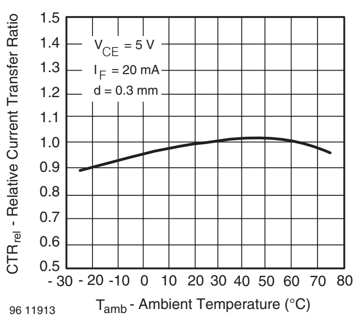


Figure 4. Relative Current Transfer Ratio vs. Ambient Temperature

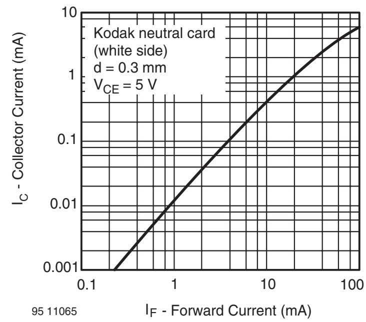


Figure 5. Collector Current vs. Forward Current

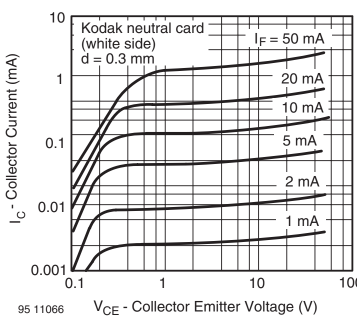


Figure 6. Collector Current vs. Collector Emitter Voltage

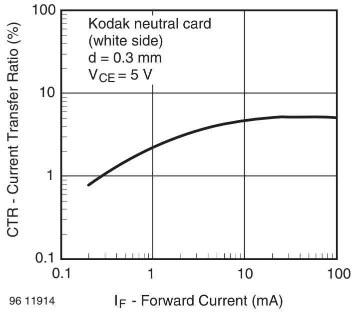


Figure 7. Current Transfer Ratio vs. Forward Current

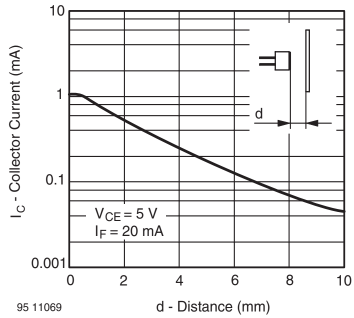


Figure 9. Collector Current vs. Distance

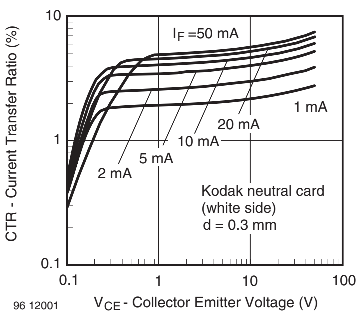


Figure 8. Current Transfer Ratio vs. Collector Emitter Voltage

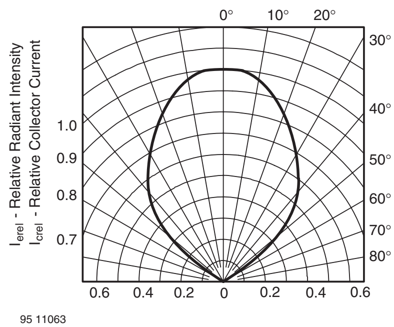


Figure 10. Relative Radiant Intensity/Collector Current vs. Angular Displacement

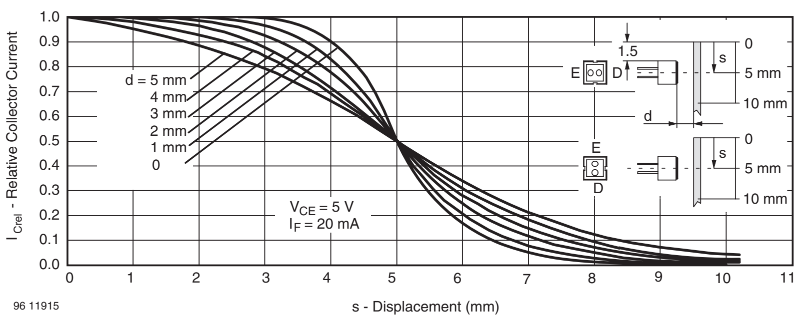
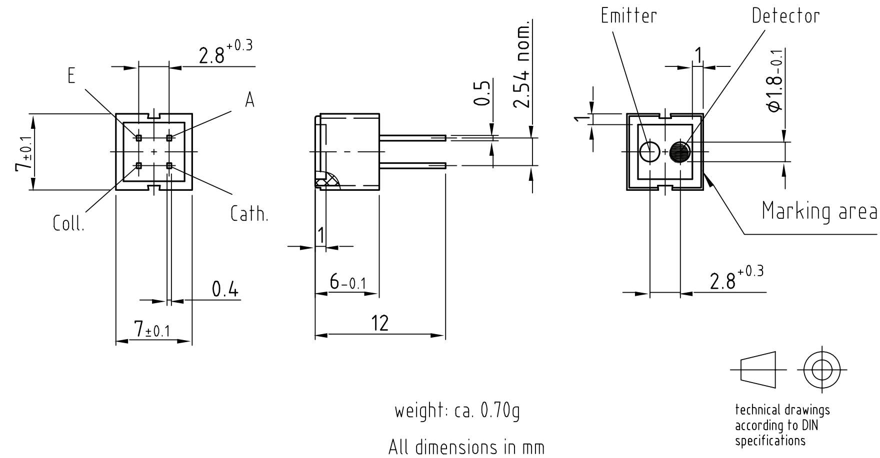


Figure 11. Relative Collector Current vs. Displacement

Package Dimensions



weight: ca. 0.70g

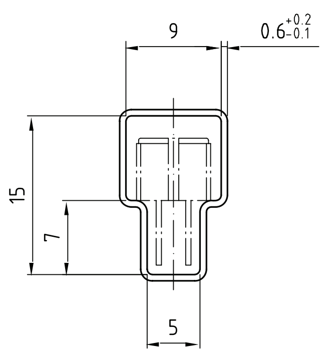
All dimensions in mm

Drawing-No.: 6.544-5062.01-4
Issue: 6; 03.05.06

Drawing refers to following types: CNY 70

95 11345

Tube Dimensions



With rubber stopper
Tolerance: ±0.5mm
Length: 575±1mm

All dimensions in mm

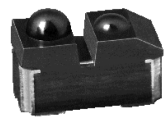
Drawing-No.: 9.700-5097.01-4
Issue: 1; 25.02.00

20291

Reflective Sensor for Touchless Switch

Description

TCND3000 is a reflective optical sensor for applications using the HALIOS® (High Ambient Light Independent Optical System) principle. It consists of an infrared emitter and a photodetector forming the optical sensing path. According to the HALIOS principle a second infrared emitter is used for compensation of disturbing ambient light. Optoelectronic parameters of the sensor are matched to the corresponding integrated circuit E909.01, manufactured by ELMOS Semiconductor AG (www.elmos.de).



Features

- Package type: Surface mount
- Detector type: PIN Photodiode
- Dimensions:
  L 4.83 mm x W 2.54 mm x H 2.21 mm
- Peak operating distance: 20 mm
- Peak operating range: 10 mm to 20 mm
- Typical output current under test: I_C = 5.6 µA
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC
- Emitter wavelength: 885 nm
- Daylight blocking filter
- Touch distance: 10 mm*)
- Proximity distance: 20 mm*)
- High ambient light suppression for sunlight: ≤ 200 klx
- High ambient light suppression for CIE standard illuminant A: ≤ 100 klx
- Minimum order quantity 800 pcs, 800 pcs/reel

*) Using E909.01 interface ASIC and Kodak grey card with 20 % diffuse reflection

Applications

- Optical switches for general purpose

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Sensor

Parameter	Test condition	Symbol	Value	Unit
Power dissipation	T_{amb} ≤ 25 °C	P_V	180	mW
Storage temperature range		T_{stg}	- 40 to + 100	°C
Operating temperature range		T_{amb}	- 40 to + 85	°C
Thermal resistance junction/ambient		R_{thJA}	450	K/W
Soldering temperature	acc. figure 7	T_{sd}	260	°C

IR Emitter LEDS (Transmitter)

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_{RS}	5	V
Forward current		I_{FS}	50	mA
Peak forward current	T_s = 8 µs t_{ps} = 4 µs	I_{FS}	100	mA
Junction temperature		T_{js}	105	°C

IR Emitter LEDC (Compensation)

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_{RC}	5	V
Forward current		I_{FC}	50	mA
Peak forward current	T_s = 8 µs t_{pc} = 4 µs	I_{FC}	100	mA
Junction temperature		T_{js}	105	°C

Detector

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_{RD}	5	V
Junction temperature		T_{jD}	105	°C

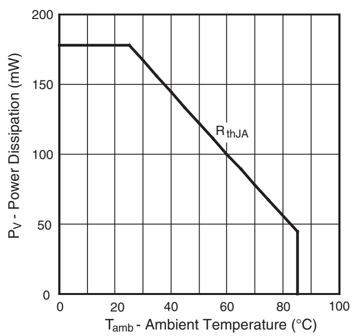


Figure 1. Power Dissipation Limit vs. Ambient Temperature

Electrical Characteristics

T_{amb} = 25 °C, unless otherwise specified

Sensor

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Light current	Kodak Grey Card 20 % diffuse reflection distance: 1 cm I_{FS} = 10 mA	I_{CA}		1.2		µA
Optical crosstalk sensing path	no reflective medium I_{FS} = 10 mA	I_{CA}		0.9		µA
Compensation current	I_{FC} = 2 mA	I_{CR}		5		µA

IR Emitter LEDS (Transmitter)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	I_{FS} = 10 mA t_p = 20 ms	V_{FS}		1.3		V
Reverse voltage	I_{RS} = 10 µA	V_{RS}	5			V
Junction capacitance		C_{jS}		50		pF
Radiant intensity	I_{FS} = 10 mA t_p = 20 ms	I_e		2	22	mW/sr
Angle of half intensity		φ_S		± 20		deg
Peak wavelength	I_{FS} = 10 mA	λ_{ps}	875	885		nm
Spectral bandwidth	I_{FS} = 10 mA	$\Delta\lambda_s$		42		nm
Virtual source diameter	DIN EN ISO 1146/1:2005	Ø		1.4		mm

IR Emitter LEDC (Compensation)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	I_{FC} = 10 mA t_{pC} = 20 ms	V_{FC}		1.3		V
Reverse voltage	I_{RC} = 10 µA	V_{RC}	5			V
Junction capacitance		C_{jC}		50		pF
Peak wavelength	I_{FC} = 10 mA	λ_{pC}		885		nm
Spectral bandwidth	I_{FC} = 10 mA	$\Delta\lambda_C$		42		nm

Detector

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	I_{FD} = 50 mA	V_{FD}		1.0	1.3	V
Breakdown voltage	I_{RD} = 100 µA E = 0	$V_{(BR)}$	5			V
Reverse dark current	V_{RD} = 10 V, E = 0	I_{r0}		1	10	nA
Reverse light current	E_e = 1 mW/cm^2 λ = 870 nm V_{RD} = 5 V	I_{ra}		5.6		µA
Temp. coefficient of I_{ra}	V_{RD} = 5 V λ = 870 nm	TK_{Ira}		0.2		%/K
Angle of half sensitivity		φ_D		± 20		deg
Wavelength of peak sensitivity		λ_p		910		nm
Range of spectral bandwidth		$\lambda_{0.5}$		790...1020		nm

Typical Characteristics

T_{amb} = 25 °C unless otherwise specified

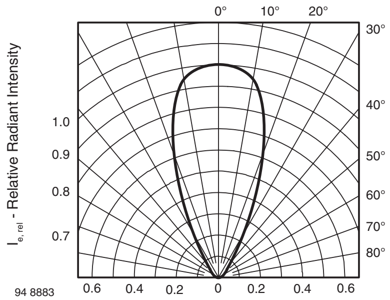


Figure 2. Relative Radiant Intensity vs. Angular Displacement

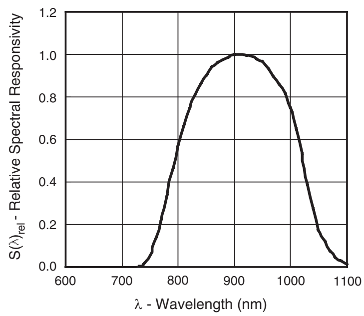


Figure 4. Relative Spectral Sensitivity vs. Wavelength

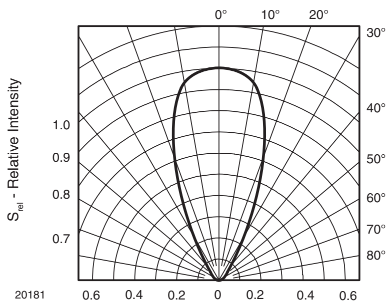


Figure 3. Relative Radiant Sensitivity vs. Angular Displacement

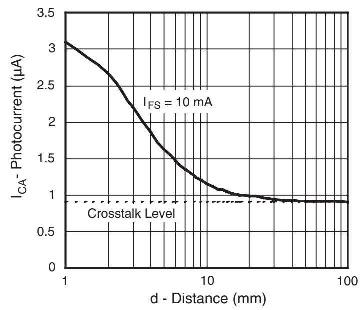


Figure 5. Photocurrent vs. Distance

Application Circuit

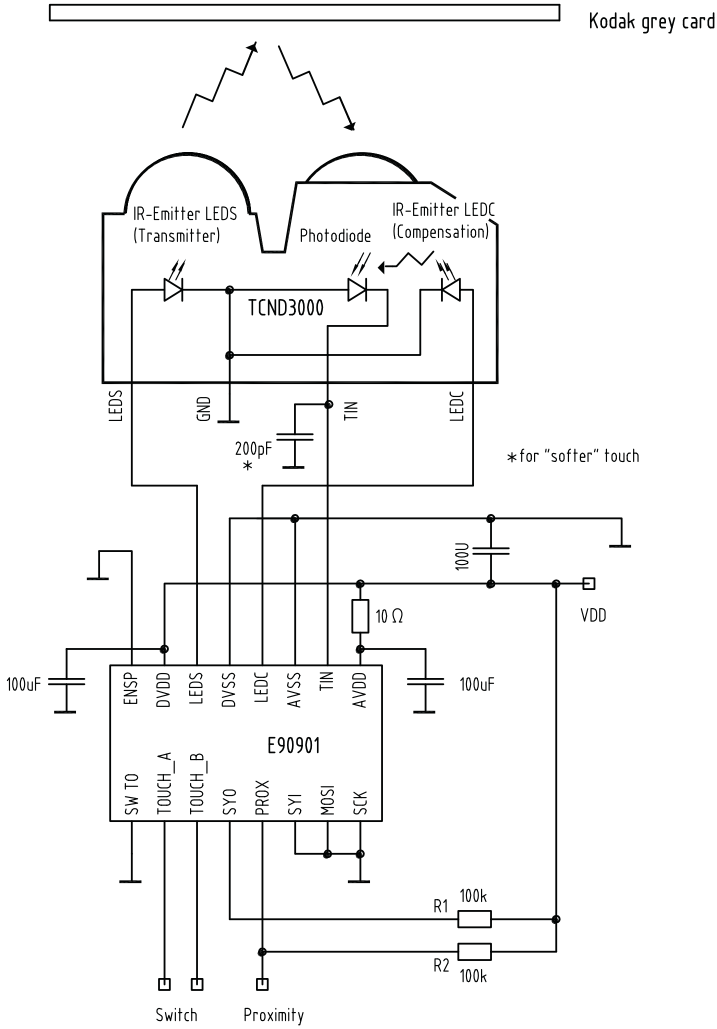
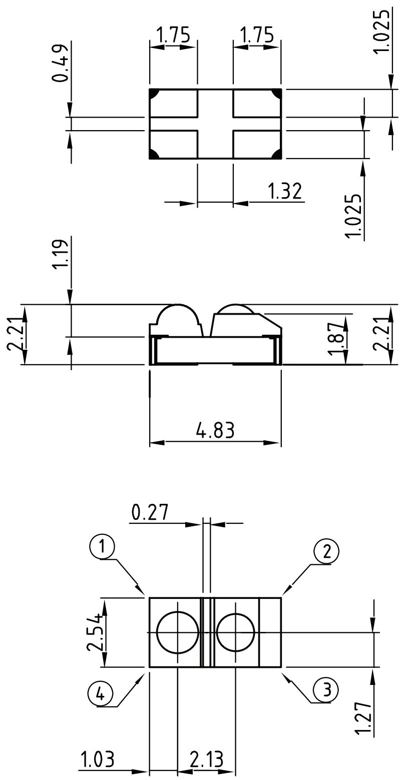


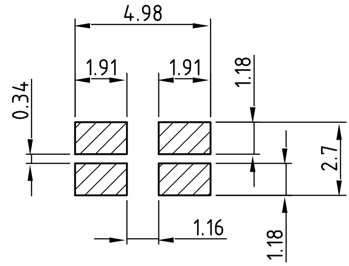
Figure 6. Test circuit

Dimensions

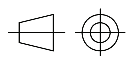
Backside Contact Metalization



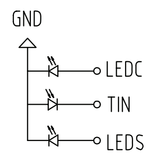
Recommened PCB Footprint



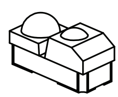
PIN	ID	FUNCTION	DESCRIPTION
1	①	LEDS	Transmit LED
2	②	TIN	Receiver Output
3	③	LEDC	Compensation LED
4	④	GND	Ground



technical drawings according to DIN specifications



SCHEMATIC



Dimensions in mm

Not indicated tolerances ±0.2

Drawing-No.: 6.550-5265.01-4
Issue: 2; 25.10.04

Reflow Solder Profiles

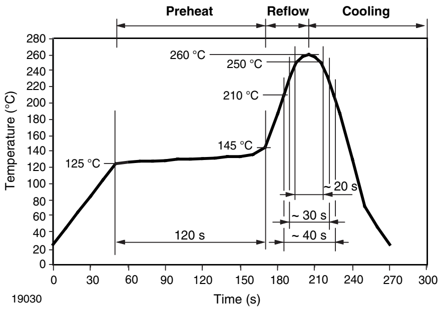


Figure 7. Lead (Pb)-Free (Sn) Reflow Solder Profile

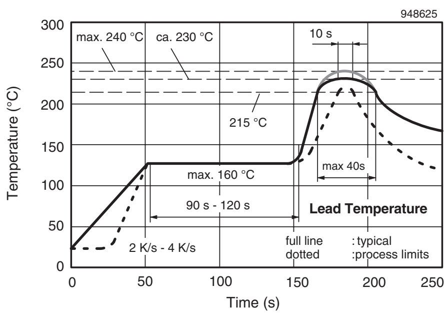


Figure 8. Lead Tin (SnPb) Reflow Solder Profile

Drypack

Devices are packed in moisture barrier bags (MBB) to prevent products from absorbing moisture during transportation and storage. Each bag contains a desiccant.

Floor Life

Floor life (time between soldering and removing from MBB) must not exceed the time indicated in J-STD-020. TCND3000 is released for: Moisture Sensitivity Level 4, according to JEDEC, J-STD-020.
Floor Life: 72 h
Conditions: T_{amb} < 30 °C, RH < 60 %

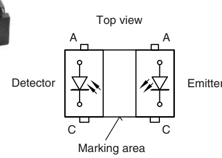
Drying

In case of moisture absorption devices should be baked before soldering. Conditions see J-STD-020 or label. Devices taped on reel dry using recommended conditions 192 h at 40 °C (± 5 °C), RH < 5 % or 96 h at 65 °C (± 5 °C), RH < 5 %.

Reflective Optical Sensor with PIN Photodiode Output

Description

The TCND5000 is a reflective sensor that includes an infrared emitter and PIN photodiode in a surface mount package which blocks visible light.



19967

Features

- Package type: Surface mount
- Detector type: PIN Photodiode
- Dimensions: L 6 mm x W 4.3 mm x H 3.75 mm
- Peak operating distance: 6 mm
- Peak operating range: 2 mm to 25 mm
- Typical output current under test: I_{ra} > 0.11 µA
- Daylight blocking filter
- High linearity
- Emitter wavelength: 940 nm
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC
- Minimum order quantity 2000 pcs, 2000 pcs/reel

Applications

- Proximity sensor
- Object sensor
- Motion sensor
- Touch key

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Input (Emitter)

Parameter	Test condition	Symbol	Value	Unit
Reverse Voltage		V_R	5	V
Forward current		I_F	100	mA
Peak Forward Current	t_p = 50 µs, T = 2 ms, T_{amb} = 25 °C	I_{FM}	500	mA
Power Dissipation		P_V	190	mW
Junction Temperature		T_j	100	°C

Output (Detector)

Parameter	Test condition	Symbol	Value	Unit
Reverse Voltage		V_R	60	V
Power Dissipation		P_V	75	mW
Junction Temperature		T_j	100	°C

Sensor

Parameter	Test condition	Symbol	Value	Unit
Operating Temperature Range		T_{amb}	- 40 to + 85	°C
Storage Temperature Range		T_{stg}	- 40 to + 100	°C
Soldering Temperature	acc. fig. 14	T_{sd}	260	°C

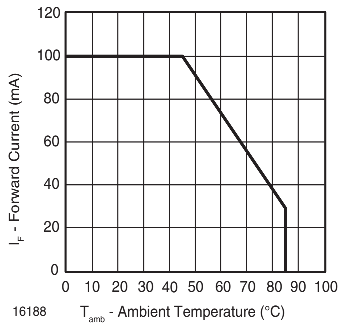


Figure 1. Forward Current Limit vs. Ambient Temperature

Electrical Characteristics

T_{amb} = 25 °C, unless otherwise specified

Input (Emitter)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward Voltage	I_F = 20 mA, t_p = 20 ms	V_F		1.2	1.5	V
Temp. Coefficient of V_F	I_F = 1 mA	TK_{VF}		- 1.3		mV/K
Reverse Current	V_R = 5 V	I_R			10	µA
Junction Capacitance	V_R = 0 V, f = 1 MHz, E = 0	C_j		25		pF
Radiant Intensity	I_F = 20 mA, t_p = 20 ms	I_e		7	75	mW/sr
Angle of Half Intensity		φ		± 12		deg
Peak Wavelength	I_F = 100 mA	λ_p	930	940		nm
Spectral Bandwidth	I_F = 100 mA	$\Delta\lambda$		50		nm
Temp. Coefficient of λ_p	I_F = 100 mA	$TK\lambda_p$		0.2		nm/K
Rise Time	I_F = 100 mA	t_r		800		ns
Fall Time	I_F = 100 mA	t_f		800		ns
Virtual Source Diameter	Method: 63 % encircled energy	Ø		1.2		mm

see figures 2 to 8 accordingly

Output (Detector)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward Voltage	I_F = 50 mA	V_F		1.0	1.3	V
Breakdown Voltage	I_R = 100 μA	V_{BR}	60			V
Reverse Dark Current	V_R = 10 V, E = 0	I_{ro}		1	10	nA
Diode capacitance	V_R = 5 V, f = 1 MHz, E = 0	C_D		1.8		pF
Reverse Light Current	E_e = 1 mW/cm^2 λ = 950 nm, V_R = 5 V	I_{ra}		12		μA
Temp. Coefficient of I_{ra}	V_R = 5 V, λ = 870 nm	TK_{ira}		0.2		%/K
Angle of Half Intensity		φ		± 15		deg
Wavelength of Peak Sensitivity		λ_p		930		nm
Range of Spectral Bandwidth		$\lambda_{0.5}$		840 to 1050		nm

see figures 9 to 12 accordingly

Sensor

T_{amb} = 25 °C, unless otherwise specified

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Reverse Light Current	V_R = 2.5 V, I_F = 20 mA D = 30 mm reflective mode: see figure 2	I_{ra}	110			nA

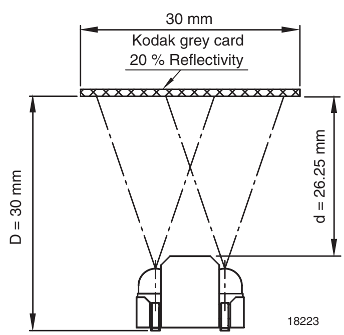


Figure 2. Test Circuit

Typical Characteristics

T_{amb} = 25 °C, unless otherwise specified

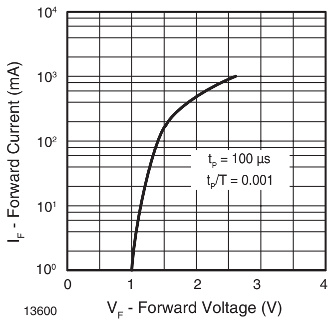


Figure 3. Forward Current vs. Forward Voltage

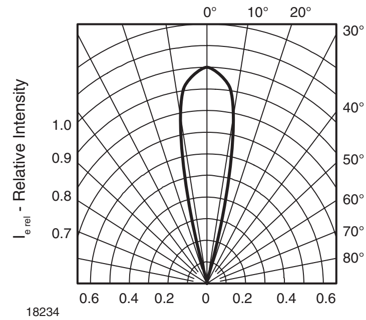


Figure 6. Relative Radiant Intensity vs. Angular Displacement

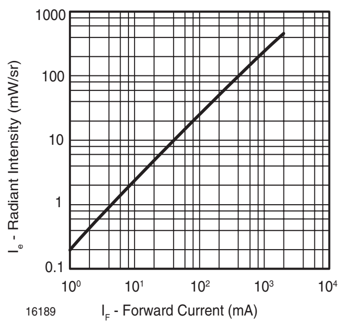


Figure 4. Radiant Intensity vs. Forward Current

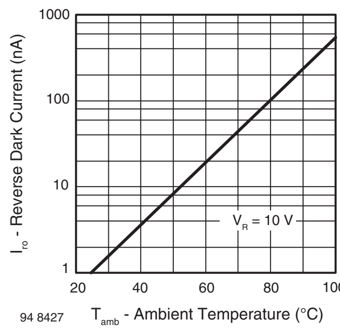


Figure 7. Reverse Dark Current vs. Ambient Temperature

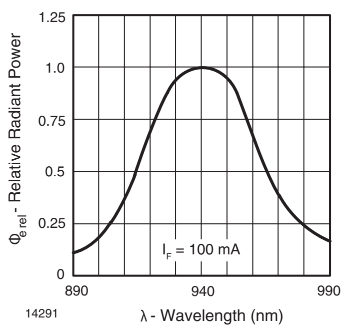


Figure 5. Relative Radiant Power vs. Wavelength

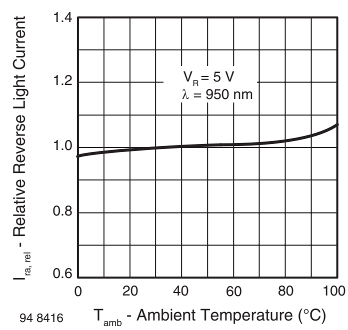


Figure 8. Relative Reverse Light Current vs. Ambient Temperature

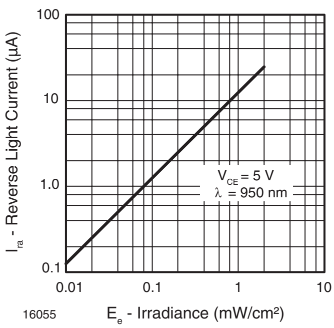


Figure 9. Reverse Light Current vs. Irradiance

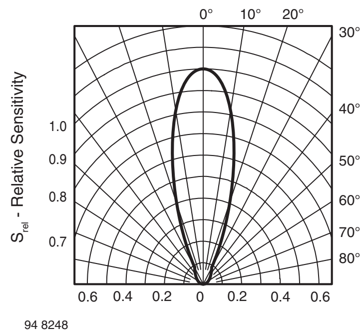


Figure 12. Relative Radiant Sensitivity vs. Angular Displacement

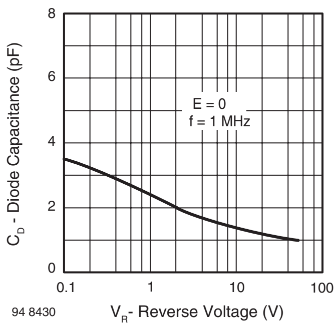


Figure 10. Diode Capacitance vs. Reverse Voltage

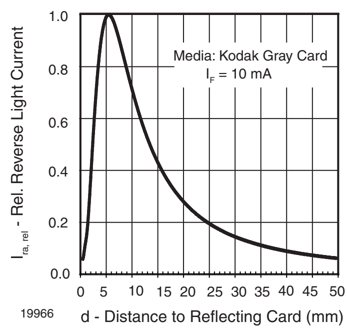


Figure 13. Relative Reverse Light Current vs. Distance

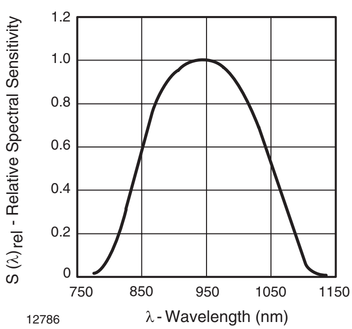
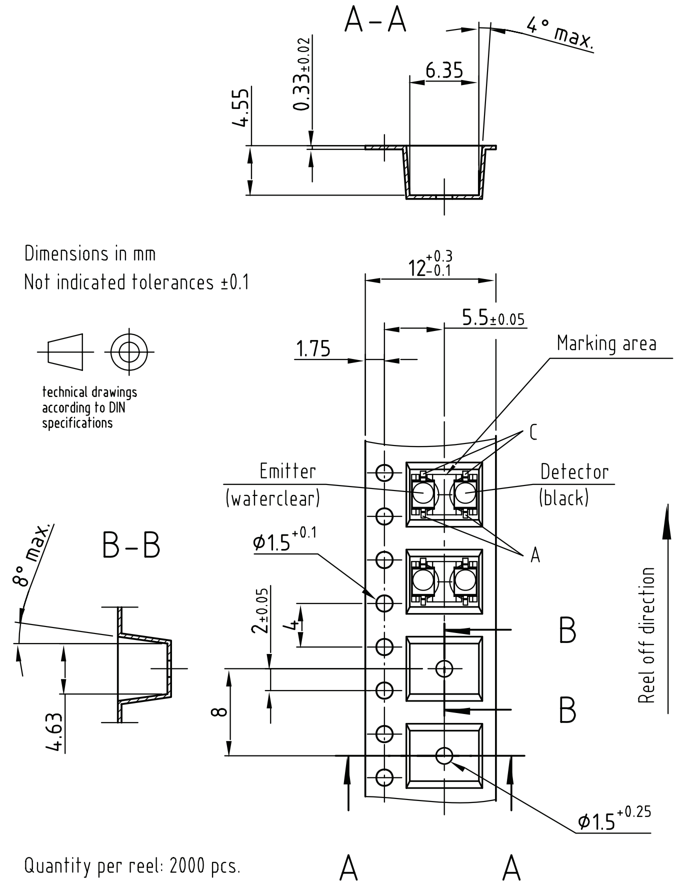


Figure 11. Relative Spectral Sensitivity vs. Wavelength

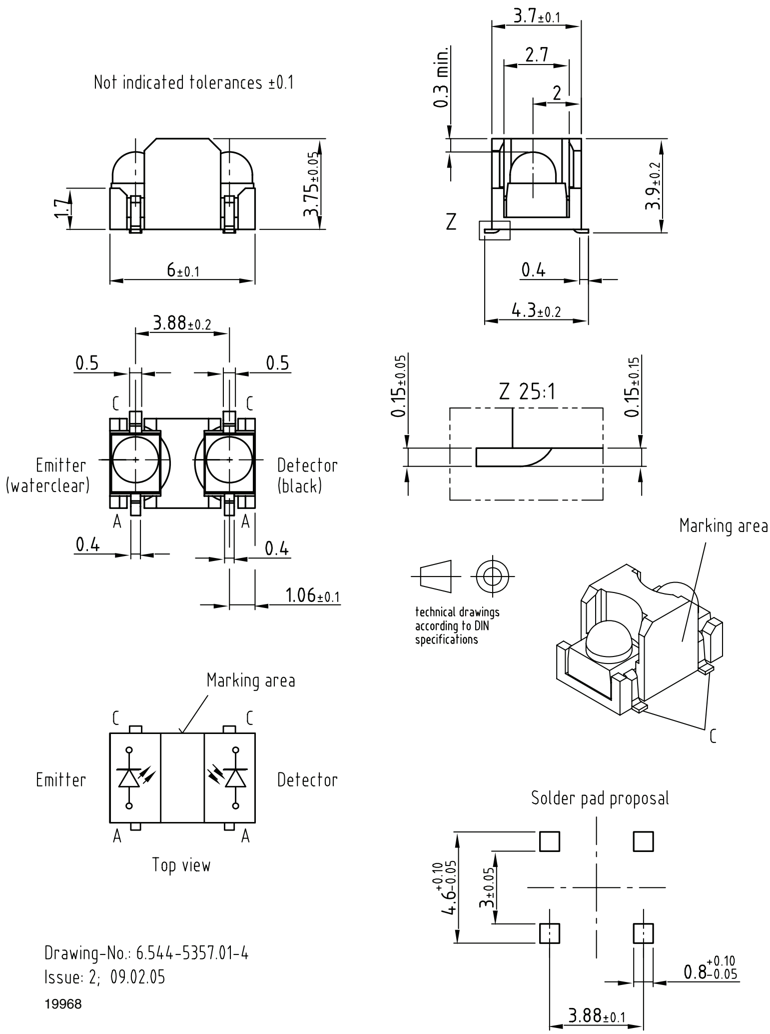
Taping



Material of Blistertape: PC black
Sealing of cavities with hot sealing cover tape,
C-Pak Type CP - 2010 AS (Thickness: 0.055 - 0.075mm; Base Material: Polyester)

Drawing-No.: 9.700-5281.01-4
Issue: 4; 10.02.05
18222

Package Dimensions in mm



Precautions For Use

1. Over-current-proof

Customer must apply resistors for protection, otherwise slight voltage shift will cause big current change (Burn out will happen).

2. Storage

2.1 Storage temperature and rel. humidity conditions are: 5 °C to 30 °C, R.H. 60 %

2.2 Floor life must not exceed 72 h, acc. to JEDEC level 4, J-STD-020.

Once the package is opened, the products should be used within 72 h. Otherwise, they should be kept in a damp proof box with desiccant.

Considering tape life, we suggest to use products within one year from production date.

2.3 If opened more than 72 h in an atmosphere 5 °C to 30 °C, R.H. 60 %, devices should be treated at 60 °C ± 5 °C for 15 hrs.

2.4 If humidity indicator in the package shows pink color (normal blue), then devices should be treated with the same conditions as 2.3

Reflow Solder Profiles

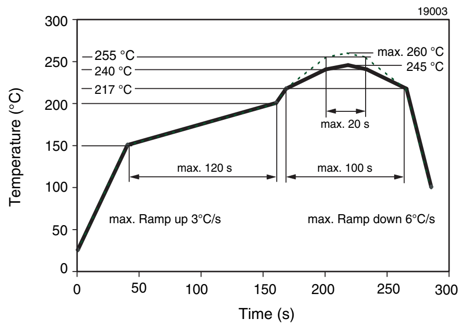


Figure 14. Lead (Pb)-Free Reflow Solder Profile

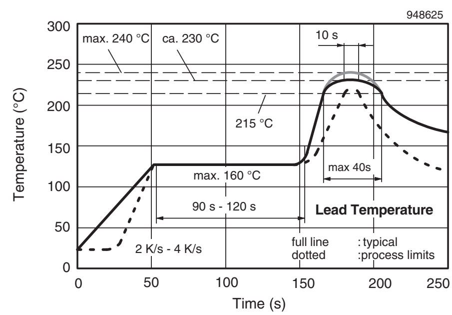
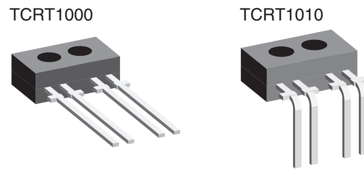


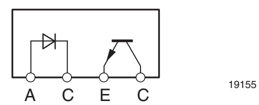
Figure 15. Lead Tin (SnPb) Reflow Solder Profile

Reflective Optical Sensor with Transistor Output

Description

The TCRT1000 and TCRT1010 are reflective sensors which include an infrared emitter and phototransistor in a leaded package which blocks visible light.





Features

- Package type: Leaded
- Detector type: Phototransistor
- Dimensions:
  L 7 mm x W 4 mm x H 2.5 mm
- Peak operating distance: 1 mm
- Operating range: 0.2 mm to 4 mm
- Typical output current under test: I_C = 0.5 mA
- Daylight blocking filter
- Emitter wavelength: 950 nm
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC

Applications

Optoelectronic scanning and switching devices i.e., index sensing, coded disk scanning etc. (optoelectronic encoder assemblies for transmissive sensing).

Order Instructions

Part Number	Remarks	Minimum Order Quantity
TCRT1000	Straight leads	1000 pcs, 1000 pcs/bulk
TCRT1010	Bent leads	1000 pcs, 1000 pcs/bulk

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Value	Unit
Total power dissipation	$T_{amb} \leq 25$ °C	P_{tot}	200	mW
Ambient temperature range		T_{amb}	- 40 to + 85	°C
Storage temperature range		T_{stg}	- 40 to + 100	°C
Soldering temperature	2 mm distance to package, $t \leq 5$ s	T_{sd}	260	°C

Input (Emitter)

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_R	5	V
Forward current		I_F	50	mA
Forward surge current	$t_p \leq 10$ µs	I_{FSM}	3	A
Power dissipation	$T_{amb} \leq 25$ °C	P_V	100	mW
Junction temperature		T_j	100	°C

Output (Detector)

Parameter	Test condition	Symbol	Value	Unit
Collector emitter voltage		V_{CEO}	32	V
Emitter collector voltage		V_{ECO}	5	V
Collector current		I_C	50	mA
Power dissipation	$T_{amb} \leq 25$ °C	P_V	100	mW
Junction temperature		T_j	100	°C

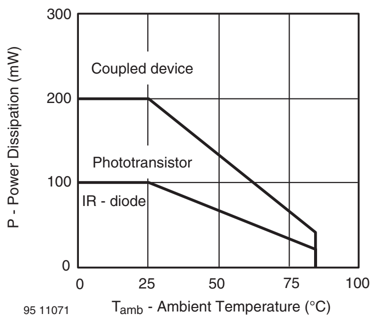


Figure 1. Power Dissipation Limit vs. Ambient Temperature

Electrical Characteristics

$T_{amb} = 25$ °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector current	$V_{CE} = 5$ V, $I_F = 20$ mA, d = 1 mm (figure 2)	I_C 1)	0.3	0.5		mA
Cross talk current	$V_{CE} = 5$ V, $I_F = 20$ mA (figure 1)	I_{CX} 2)			1	µA
Collector emitter saturation voltage	$I_F = 20$ mA, $I_C = 0.1$ mA, d = 1 mm (figure 2)	V_{CEsat} 1)			0.3	V

1) Measured with the ‘Kodak neutral test card", white side with 90 % diffuse reflectance

2) Measured without reflecting medium

Input (Emitter)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	I_F = 50 mA	V_F		1.25	1.6	V
Radiant intensity	I_F = 50 mA, t_P = 20 ms	I_e			7.5	mW/sr
Peak wavelength	I_F = 100 mA	λ_P	940			nm
Virtual source diameter	Method: 63 % encircled energy	Ø		1.2		mm

Output (Detector)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector emitter voltage	I_C = 1 mA	V_{CEO}	32			V
Emitter collector voltage	I_E = 100 µA	V_{ECO}	5			V
Collector dark current	V_{CE} = 20 V, I_F = 0, E = 0	I_{CEO}			200	nA

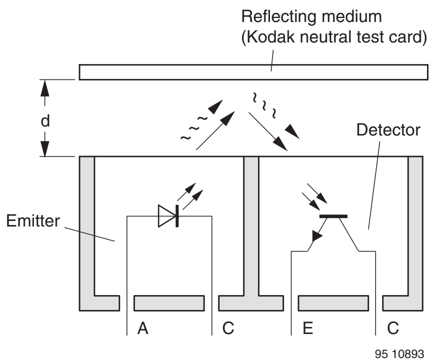


Figure 2. Test Condition

Typical Characteristics

T_{amb} = 25 °C, unless otherwise specified

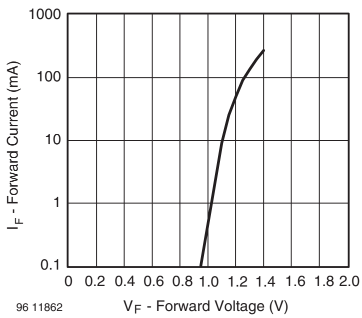


Figure 3. Forward Current vs. Forward Voltage

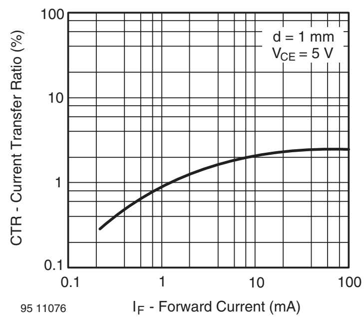


Figure 6. Current Transfer Ratio vs. Forward Current

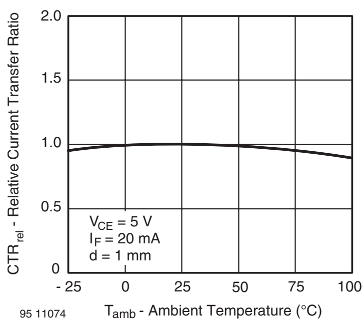


Figure 4. Relative Current Transfer Ratio vs. Ambient Temperature

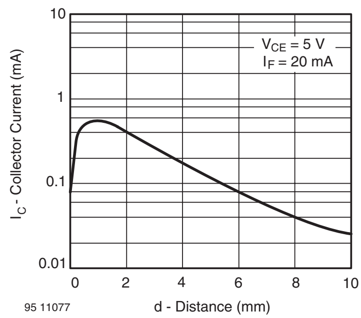


Figure 7. Collector Current vs. Distance

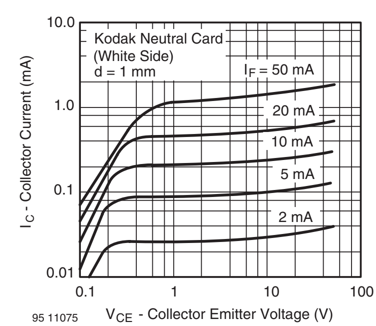


Figure 5. Collector Current vs. Collector Emitter Voltage

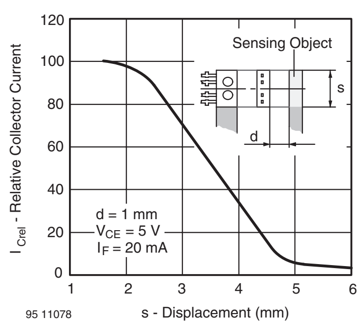
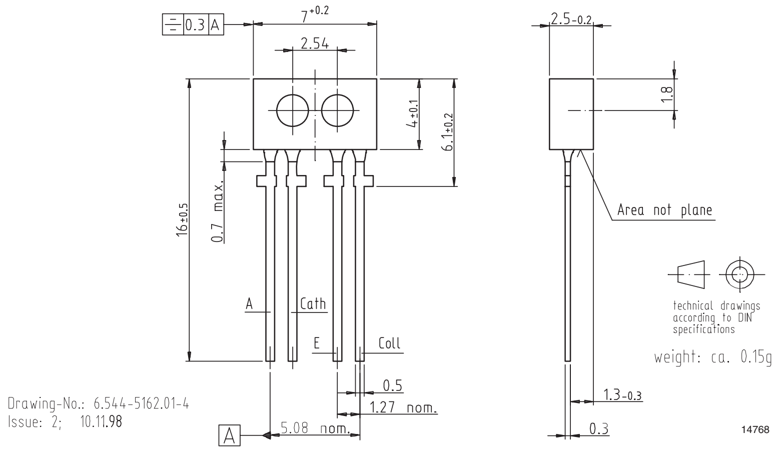
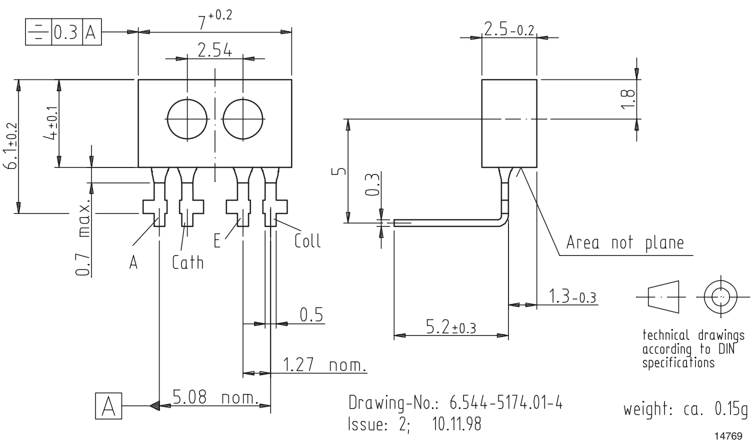


Figure 8. Relative Collector Current vs. Displacement

Package Dimensions in mm

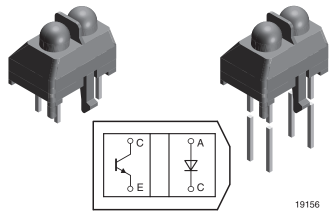




Reflective Optical Sensor with Transistor Output

Description

The TCRT5000 and TCRT500L are reflective sensors which include an infrared emitter and phototransistor in a leaded package which blocks visible light. The package includes two mounting clips. TCRT5000L is the long lead version.



Top view

Features

- Package type: Leaded
- Detector type: Phototransistor
- Dimensions:
  L 10.2 mm x W 5.8 mm x H 7.0 mm
- Peak operating distance: 2.5 mm
- Operating range: 0.2 mm to 15 mm
- Typical output current under test: I_C = 1 mA
- Daylight blocking filter
- Emitter wavelength: 950 nm
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC

Applications

- Position sensor for shaft encoder
- Detection of reflective material such as paper, IBM cards, magnetic tapes etc.
- Limit switch for mechanical motions in VCR
- General purpose - wherever the space is limited

Order Instructions

Part Number	Remarks	Minimum Order Quantity
TCRT5000	3.5 mm lead length	4500 pcs, 50 pcs/tube
TCRT5000L	15 mm lead length	2400 pcs, 48 pcs/tube

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Input (Emitter)

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_R	5	V
Forward current		I_F	60	mA
Forward surge current	$t_p \leq 10$ µs	I_{FSM}	3	A
Power dissipation	$T_{amb} \leq 25$ °C	P_V	100	mW
Junction temperature		T_j	100	°C

Output (Detector)

Parameter	Test condition	Symbol	Value	Unit
Collector emitter voltage		V_{CEO}	70	V
Emitter collector voltage		V_{ECO}	5	V
Collector current		I_C	100	mA
Power dissipation	$T_{amb} \leq 55$ °C	P_V	100	mW
Junction temperature		T_j	100	°C

Sensor

Parameter	Test condition	Symbol	Value	Unit
Total power dissipation	$T_{amb} \leq 25$ °C	P_{tot}	200	mW
Operation temperature range		T_{amb}	- 25 to + 85	°C
Storage temperature range		T_{stg}	- 25 to + 100	°C
Soldering temperature	2 mm from case, t ≤ 10 s	T_{sd}	260	°C

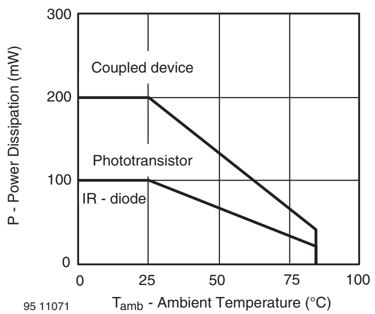


Figure 1. Power Dissipation Limit vs. Ambient Temperature

Electrical Characteristics

T_{amb} = 25 °C, unless otherwise specified

Input (Emitter)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	I_F = 60 mA	V_F		1.25	1.5	V
Junction capacitance	V_R = 0 V, f = 1 MHz	C_j		17		pF
Radiant intensity	I_F = 60 mA, t_P = 20 ms	I_E			21	mW/sr
Peak wavelength	I_F = 100 mA	λ_P	940			nm
Virtual source diameter	Method: 63 % encircled energy	Ø		2.1		mm

Output (Detector)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector emitter voltage	I_C = 1 mA	V_{CEO}	70			V
Emitter collector voltage	I_E = 100 µA	V_{ECO}	7			V
Collector dark current	V_{CE} = 20 V, I_F = 0, E = 0	I_{CEO}		10	200	nA

Sensor

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector current	V_{CE} = 5 V, I_F = 10 mA, D = 12 mm	I_C [1,2]	0.5	1	2.1	mA
Collector emitter saturation voltage	I_F = 10 mA, I_C = 0.1 mA, D = 12 mm	V_{CEsat} [1,2]			0.4	V

[1] See figure 3

[2] Test surface: Mirror (Mfr. Spindler a. Hoyer, Part No 340005)

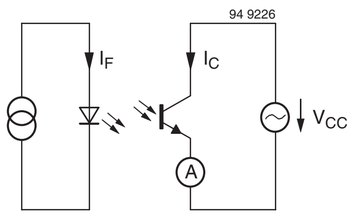


Figure 2. Test Circuit

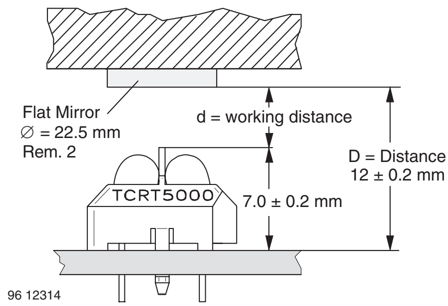


Figure 3. Test Circuit

Typical Characteristics

T_{amb} = 25 °C, unless otherwise specified

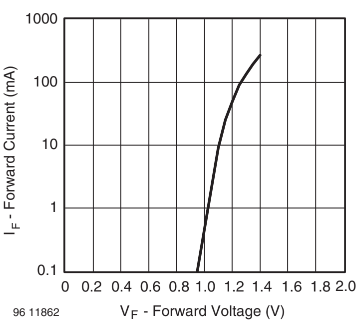


Figure 4. Forward Current vs. Forward Voltage

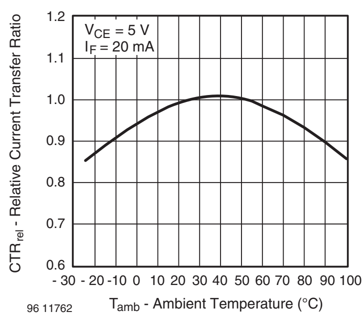


Figure 5. Relative Current Transfer Ratio vs. Ambient Temperature

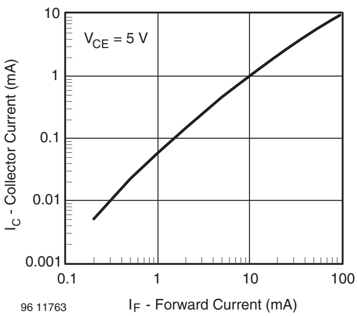


Figure 6. Collector Current vs. Forward Current

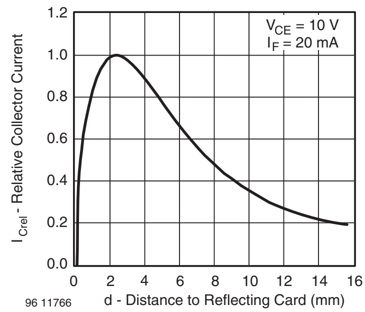


Figure 9. Relative Collector Current vs. Distance

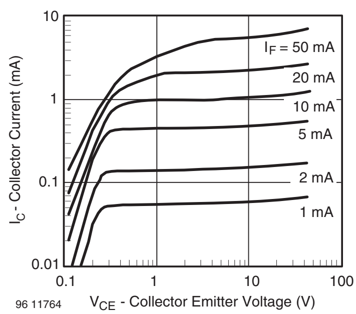


Figure 7. Collector Emitter Saturation Voltage vs. Collector Current

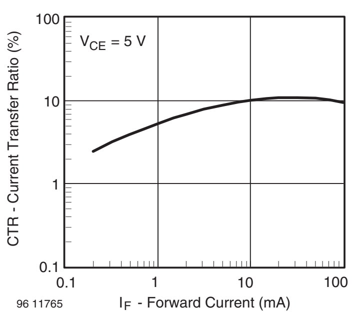
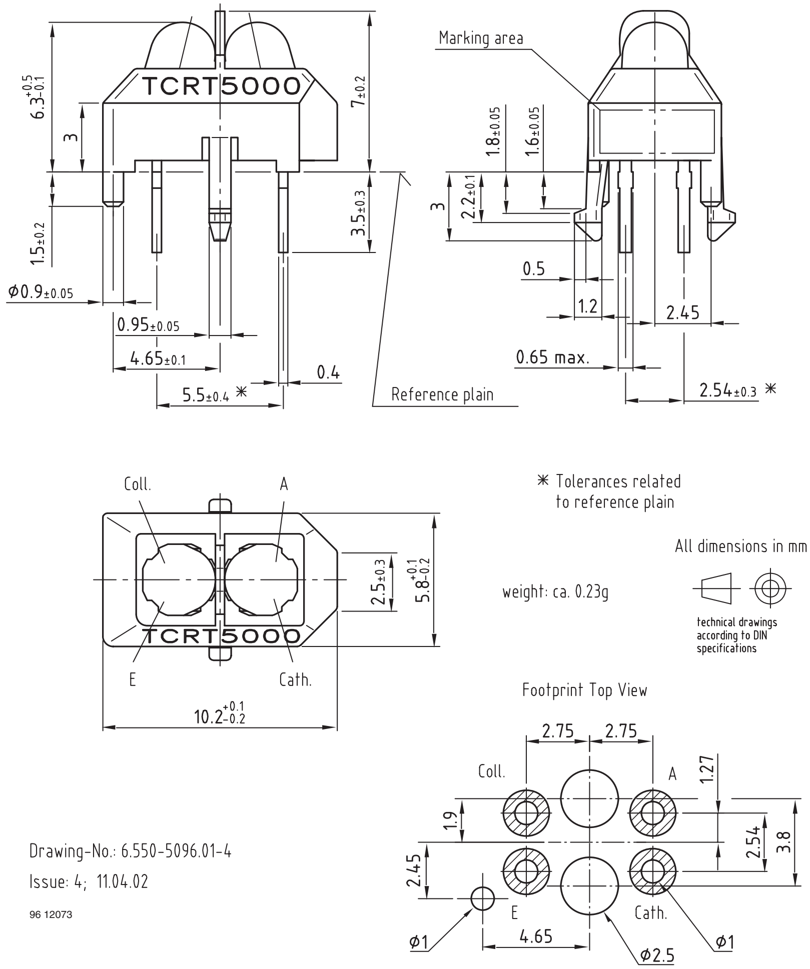
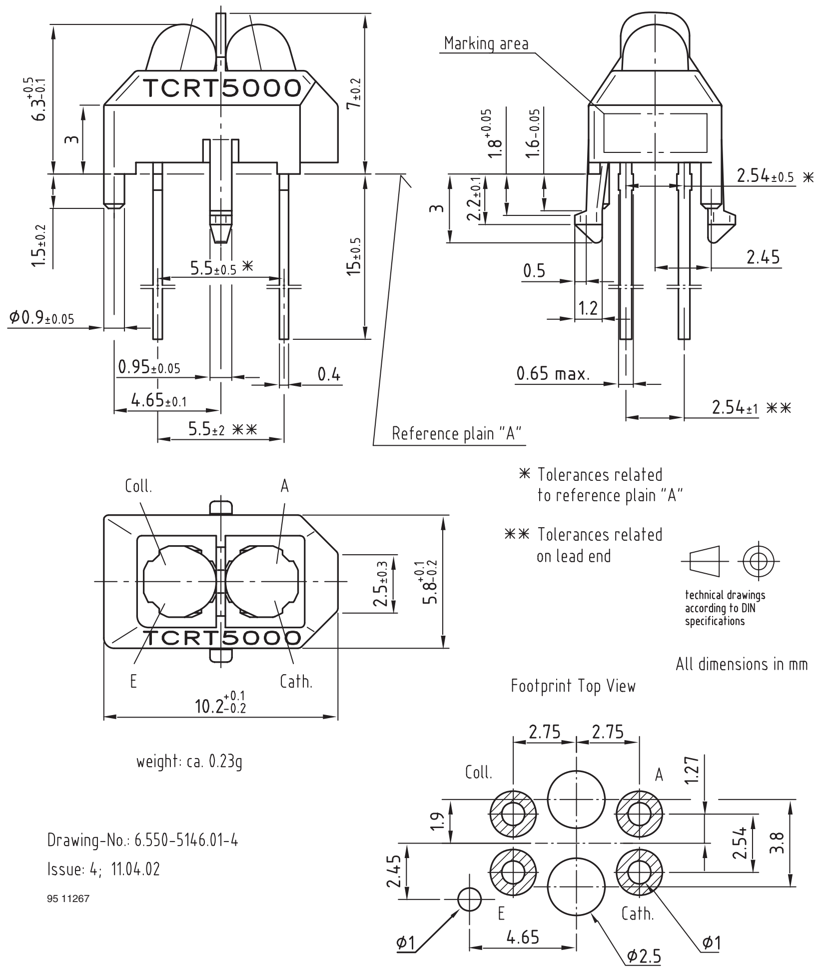


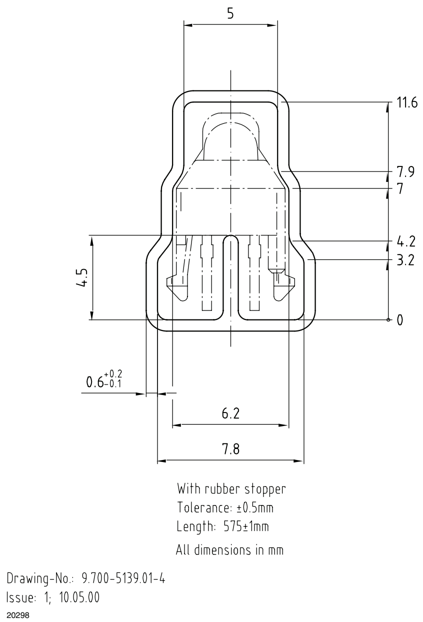
Figure 8. Current Transfer Ratio vs. Forward Current

Package Dimensions in mm

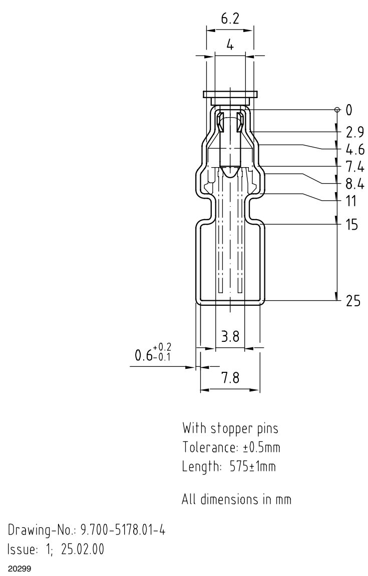



TCRT5000
Marking area
Reference plain "A"
Coll.
A
E
Cath.
✳ Tolerances related to reference plain "A"
✳✳ Tolerances related on lead end
technical drawings according to DIN specifications
All dimensions in mm
Footprint Top View
weight: ca. 0.23g
Drawing-No.: 6.550-5146.01-4
Issue: 4; 11.04.02
95 11267

TCRT5000, Tube Dimensions



TCRT5000L, Tube Dimensions



Transmissive Sensors

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Optical Sensors - Transmissive

Vishay is a leading manufacturer of optical sensors. These sensors integrate an infrared emitter and photo detector in a single package. The most common types of optical sensors are transmissive and reflective sensors. Both types detect the presence of an object without any mechanical or electrical contact. The output signal of the sensor is used to control various functions of an application.

Transmissive sensors, also called interrupter sensors, incorporate an infrared emitter and photo detector that face each other as shown in Figure 1. When an object is located between the emitter and detector in the sensing path, it interrupts or breaks the optical beam of the emitter. The light energy reaching the detector changes. This change in light energy or photo current is used to affect an event in the application.

Reflective sensors incorporate an infrared emitter and photo detector adjacent to each other as shown in Figure 2. When an object is in the sensing area, the emitted light is reflected back towards the photo detector, the amount of light energy reaching the detector increases. This change in light energy or photo current is similarly used an input signal in the application.

This application note describes the proper use of Vishay's transmissive sensors. It describes several factors that must be considered when using a transmissive sensor. Vishay has a broad portfolio of transmissive sensors in leaded and surface mount packages with various gap and aperture sizes. One is just right for your application. Should you have any design questions, Vishay's Application Engineers are ready to assist you.

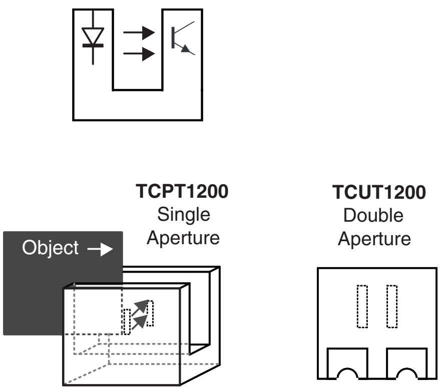


Figure 1.

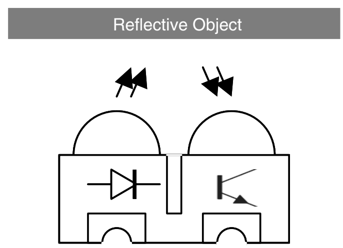


Figure 2.

Datasheet Parameter Values

The datasheets of each sensor include the absolute maximum ratings, and electrical and optical characteristics. The absolute maximum ratings of the emitter, detector and the sensor combined are provided. Maximum values for parameters like reverse and forward voltage, collector current, power dissipation, and ambient and storage temperatures are defined. The transmissive sensors must be operated within these limits. In practice, applications should be designed so that there is large margin between the operating conditions and the absolute maximum ratings. The electrical and optical characteristics indicate the performance of the sensor under specific operating conditions. Generally, the minimum and/or maximum values are provided. These values are guaranteed and are tested during the manufacture of the sensor. Typical values, while sometimes provided, should only be used as a guide in the design process. They may or may not be tested during the manufacturing process and are not guaranteed. Table 2 at the end of this note provides the symbol, parameter and definition of data found in transmissive sensor datasheets.

Document Number: 81452
Rev. 1.0, 27-Sep-06

Collector Current

If an object is moving towards the aperture, the light will be blocked and the collector current decreases, Figure 3. If the object is moving away from the aperture, the light will not be blocked and the collector current increases. Both scenarios are commonly found in transmissive sensor applications. The resolution of the transmissive sensor depends on the aperture, the light sensitive area of the detector and the direction of movement. To increase the performance of the sensor, the object should not be infrared translucent. For linear position sensing applications, only the collector current range from 90 % to 10 % can be used to avoid false detects.

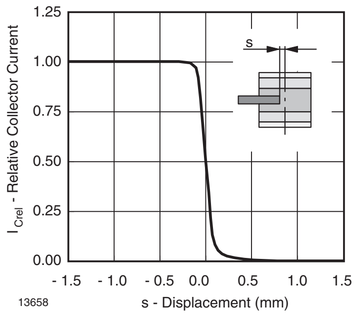


Figure 3.

Aperture, Gap Size

Most of Vishay's transmissive sensors use an aperture to focus the light onto a single plain and direction. Smaller apertures are intended to give better resolution which will result in a steeper sloped Ic. A single channel transmissive sensor has one emitter and detector pointing at each other while a dual channel sensor will have one emitter and two detectors, and apertures, Figure 4, 5, 6. Single channel sensors are used to detect the presence or absence of an object and to detect speed. Dual channel sensors are commonly used to detect direction and speed using quadrature encoding.

The medium or object to be sensed plus its tolerances normally defines the minimum gap size. Assembly tolerances and other factors relating to the type of medium will add to this gap size. The ideal gap size accounts for all of these factors and is no larger than necessary. This ensures the optimum current transfer ratio for the system. If the gap size is too big, stray ambient light may interfere with the signal, emitted light will diffuse and the current transfer ratio will not be optimum.

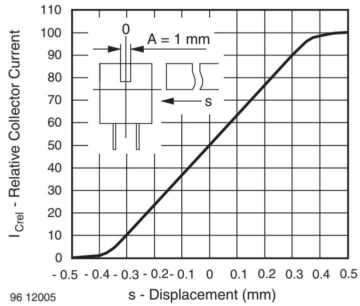


Figure 4. Rel.Rel. Collector Current vs. Displacement

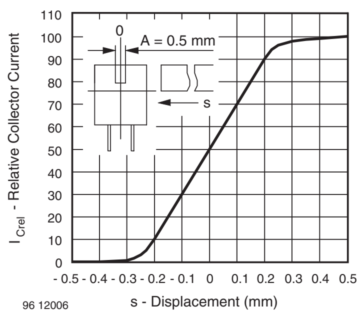


Figure 5. Rel. Rel. Collector Current vs. Displacement

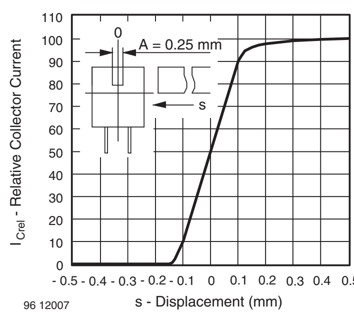


Figure 6. Rel. Collector Current vs. Displacement

Dark Current

When a phototransistor is placed in the dark, or zero ambient illumination, and a voltage is applied from collector to emitter, a certain amount of current will flow. This current is called the dark current. It consists of the leakage current of the collector-base junction multiplied by the DC current gain of the transistor. The presence of this current prevents the phototransistor from being considered completely "off" or being an ideal "open switch". In datasheets, the dark current is described as being the maximum collector current permitted to flow at a given collector-emitter voltage. The dark current is a function of this voltage and temperature, Figure 7.

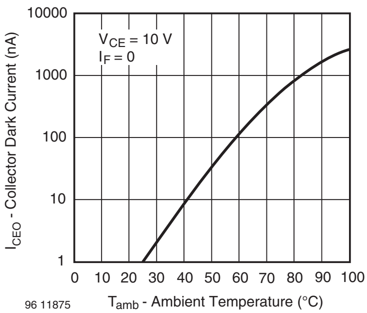


Figure 7. Collector Dark Current vs. Ambient Temperature

Temperature

Photo transistors and infrared emitting diodes are temperature dependent. As temperature increases, the light and dark current increases while emitter output decreases. Radiant intensity of the emitter decreases by - 0.7 %/°C while the sensitivity of the phototransistor increases by + 1 %/°C. So, an increase in the light current of the phototransistor is off-set by a decrease in the output of the emitter, Figure 8 and 9. Consequently, the change in the output of transmissive sensors due to temperature change is comparatively small at less than 10 % from - 25 °C to + 70 °C, Figure 10. Because of this, it is not recommended or necessary to try to compensate for changes in temperature in the design of transmissive sensor circuit.

Temperature also plays an important role in determining the emitter forward current in the application. As an example, if the maximum forward current at an ambient temperature of 25 °C is 50 mA. As shown in Figure 11, as power dissipation decreases the forward current must be reduced according to changes in the ambient temperature. At an ambient temperature is 85 °C, the maximum current is roughly 20 % of the value at 25 °C. In practice, the actual current should include a large safety margin and the lowest possible current should be used.

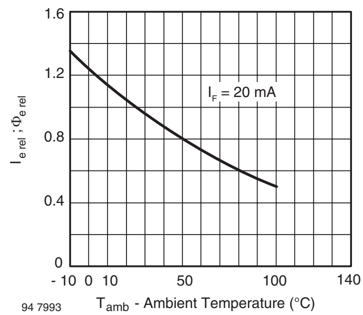


Figure 8. Rel. Radiant Intensity/Power vs. Ambient Temperature

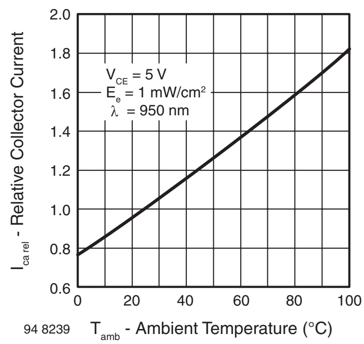


Figure 9. Rel. Collector Current vs. Ambient Temperature

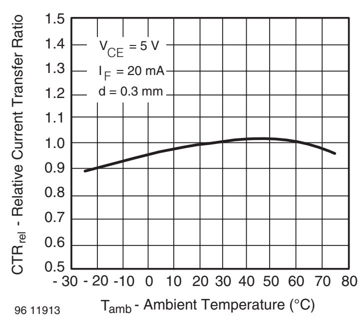


Figure 10. Rel. Current Transfer Ratio vs. Ambient Temperature

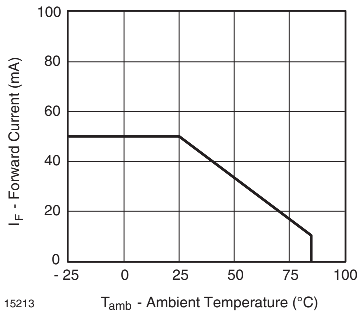


Figure 11. Forward Current vs. Ambient Temperature

Ambient Light

Ambient light can impair the sensitivity of the transmissive sensor though its effect is reduced compared to reflective sensors because of relative small gap sizes and the in-line nature of the emitter and detector. Steady light falling directly on the detector may saturate the phototransistor. If an object intended to block the light path does not block the direct ambient light, the phototransistor may remain saturated and no signal will be generated. Varying ambient light results in incorrect signals and missed detections. In many applications, it is difficult to precisely determine the ambient light and its effects. Therefore, the influence of ambient light must be minimized by using optical filters, inspired mechanical design and, if necessary, AC operation. Most of Vishay's transmissive sensors are molded from epoxy that blocks visible light. Still, a large portion of sunlight is in the infrared. Locate or house the sensor so it is recessed to eliminate direct light. Pulsed operation can be helpful in some applications. AC operation is the most effective protection against ambient light.

Emitter Intensity

Emitter intensity depends largely on the forward current, I_F. The absolute maximum forward current is found in the datasheet. For some of Vishay's transmissive sensors, the maximum forward current is 25 mA at an ambient temperature of 25°C. If the forward current is too low, the optical output of the emitter will not be stable. A current limiting resistor is required. Without it, the current of the diode is theoretically limitless and the diode will burn out. The value of the current limiting resistor is calculated using the formula:

$$R_L = (V_{CC} - V_F) / I_F$$

where the forward voltage of the emitter, V_F, typically 1.2 V, is subtracted from the supply voltage, V_{CC}, and divided by the forward current. Again, design in safety margin between actual operating conditions and the absolute maximum ratings. Intensities that are too high will reduce response time and potentially accelerate degradation. However, since the emitter points directly at the detector over a small gap, forward currents for transmissive sensors are typically low.

Switching Times

The speed of response of a phototransistor is dominated by the capacitance of the collector-base junction and the value of the load resistance. A phototransistor takes a certain amount of time to respond to sudden changes in light intensity. The response time is usually expressed by the rise time and fall time of the detector. If the light source driving the phototransistor is not intense enough to cause optical saturation, characterized by the storage of excess amounts of charge carriers in the base region, rise time equals fall time. Transmissive sensors are generally saturated when an object is not present so fall time is larger than rise time. The selection of the load resistor, R_L, will also determine the amount of current-to-voltage conversion in the circuit. Reducing the value of R_L may result in a faster response time at the expense of a smaller voltage signal.

Degradation

End-users purchasing a transmissive sensor want an accurate estimate of how long the sensor will last. Many will have minimum life requirements. Unlike most traditional light sources, infrared emitting diodes do not fail catastrophically. Instead, the light output degrades over time, Figure 12. Therefore the useful life of a transmissive sensor can be defined by the time when it fails to provide sufficient light for the intended application. Infrared and visible light emitting diode life is often quoted to be 100000 hours but this is based on the average life span of a single, 5 mm epoxy encapsulated emitter. Vishay's reflective sensors also have a single emitter that is epoxy encapsulated. With some similarity, average life span can be considered comparable. As a rule-of-thumb, plan for 30 % degradation of the emitter over the life time of the sensor.

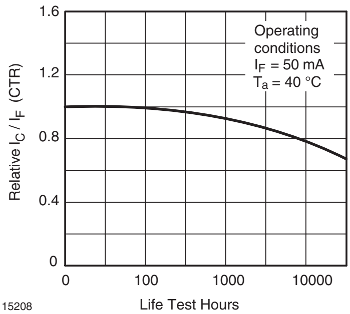


Figure 12.

The three main causes of degradation are:

- A loss of efficiency caused by mechanical stress deforming the crystal structure
- A loss of optical coupling caused by delamination between epoxy and chip
- A loss of efficiency caused by thermal stress on the crystal structure

The rate of degradation or aging is affected by:

- Chip technology: GaAs and GaAIAs Double Hetero (DH) technologies result in lower rates, while GaAIAs and GaAIAs/GaAs technologies result in higher rates of aging
- Package technology: metal can packaging technologies result in lower rates, and epoxy packaging technologies result in higher rates of aging
- Chip size: The smaller the chip, the higher the current density. A higher current density results in faster aging

There are a number of ways to minimize emitter degradation or aging. First, minimize the junction temperature. As long as the junction temperature, T_J, is kept below 100 °C, heating of the pn-junction will cause no significant degradation. To reduce junction temperature, minimize the forward current and the ambient temperature. Second, in applications where there is temperature cycling, keep the forward current for the corresponding temperature well below that shown in Figure 11. This is especially important since degradation due to mechanical stress and delamination is potentially greater in epoxy-based sensors. Transmissive sensor datasheets include a curve showing Total Power Dissipation versus Ambient Temperature. Use this curve as a guide to minimize degradation.

Vishay features state-of-the-art chip technologies and high quality standards in the assembly process resulting in low degradation rate of our sensor components.

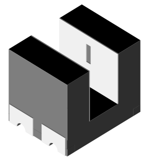
Table 2

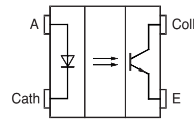
Parameter	Symbol	Definition
V_R	Reverse voltage	The maximum permissible applied voltage to the anode of the LED such that the current flows in the reverse direction
I_F	Forward Current	The direct or continuous current flowing in the forward direction of a diode, from the anode to the cathode
	Gap	Distance from emitter face (or post) to detector face
	Aperture	The opening in the detector post that admits light
I_{FSM}	Forward surge current	The maximum permissible surge or pulse current allowed for a specified temperature and period in the forward direction
P_V	Power dissipation	The maximum power that is consumed by the collector junction of a phototransistor
TJ	Junction temperature	The spatial mean value of the collector junction temperature during operation
V_{CEO}	Collector emitter voltage	The positive voltage applied to the collector of a phototransistor with the emitter at a reference potential and open base
V_{ECO}	Emitter collector voltage	The positive voltage applied to the emitter of a phototransistor with the collector at a reference potential and open base
I_C	Collector current	The current that flows to the collector junction of a phototransistor
T_{amb}	Ambient Temperature	The maximum permissible ambient temperature
T_{stg}	Storage Temperature	The maximum permissible storage temperature without an applied voltage
V_F	Forward voltage	The voltage drop across the diode in the forward direction when a specified forward current is applied
I_{CEO}	Collector dark current	The current leakage of the phototransistor when a specified bias voltage is applied so that the polarity of the collector is positive and that of the emitter is negative on condition that the illumination of the sensor is zero
V_{CEsat}	Collector emitter saturation voltage	The continuous voltage between the collector and emitter when the detector is in its "ON" state as measured with the Kodak neutral test card, white side
t_r	Rise time	Amount of time it takes the output voltage to go from 10 % of the lower specified value to 90 % of the upper specified value
t_f	Fall time	The time required for the output voltage to go from 90 % of the upper specified value to 10 % of the lower specified value

Subminiature Transmissive Optical Sensor with Phototransistor Output

Description

The TCPT1200 is a compact transmissive sensor that includes an infrared emitter and phototransistor detector, located face-to-face on the optical axes in a surface mount package.





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Features

- Package type: Surface mount
- Detector type: Phototransistor
- Dimensions:
  L 5 mm x W 4 mm x H 4 mm
- Gap: 2 mm
- Aperture: 0.3 mm
- Typical output current under test: I_C = 0.5 mA
- Emitter wavelength: 950 nm
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC
- Minimum order quantity: 2000 pcs, 2000 pcs/reel

Pb
Pb-free

e4

Applications

- Accurate position sensor for encoder
- Detection of motion direction
- Computer mouse and trackballs

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Value	Unit
Power dissipation	$T_{amb} \le 25$ °C	P	150	mW
Ambient temperature range		T_{amb}	- 40 to +85	°C
Storage temperature range		T_{stg}	- 40 to +100	°C
Soldering temperature	in accordance with fig. 13	T_{sd}	260	°C

Input (Emitter)

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_R	5	V
Forward current		I_F	25	mA
Pulse forward current	t_p = 0.1 ms; $t_{p/T}$ = 0.01	I_{FP}	100	mA
Power dissipation	$T_{amb} \le 25$ °C	P_V	75	mW

Output (Detector)

Parameter	Test condition	Symbol	Value	Unit
Collector emitter voltage		V_{CEO}	70	V
Emitter collector voltage		V_{ECO}	7	V
Collector current		I_C	20	mA
Power dissipation	$T_{amb} \le 25$ °C	P_V	75	mW

Electrical Characteristics

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector current	V_{CE} = 5 V, I_F = 15 mA	I_C	300	500		µA
Collector emitter saturation voltage	I_F = 15 mA, I_C = 0.05 mA	V_{CEsat}			0.4	V

Input (Emitter)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	I_F = 15 mA	V_F		1.2	1.5	V
Reverse current	V_R = 5 V	I_R			10	µA
Junction capacitance	V_R = 0 V, f = 1 MHz	C_j		50		pF

Output (Detector)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector emitter voltage	I_C = 1 mA	V_{CEO}	70			V
Emitter collector voltage	I_E = 100 µA	V_{ECO}	7			V
Collector dark current	V_{CE} = 25 V, I_F = 0, E = 0	I_{CEO}		10	100	nA

Switching Characteristics

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Rise time	I_C = 0.3 mA, V_{CE} = 5 V, R_L = 1000 Ω (see figure 2)	t_r		20.0	150	µs
Fall time	I_C = 0.3 mA, V_{CE} = 5 V, R_L = 1000 Ω (see figure 2)	t_f		30.0	150	µs

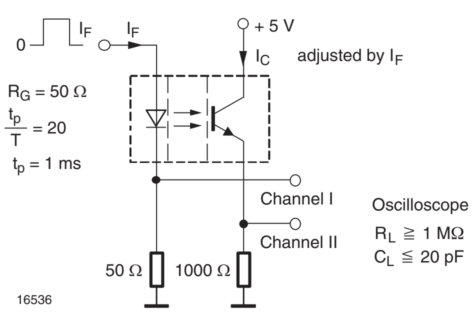


Figure 1. Test Circuit for t_r and t_f

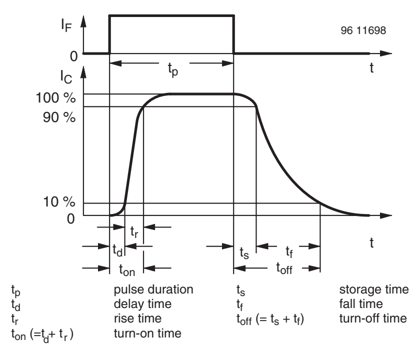


Figure 2. Switching Times

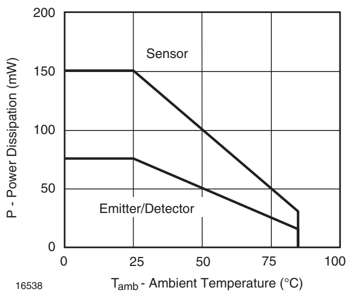


Figure 3. Power Dissipation Limit vs. Ambient Temperature

Typical Characteristics

T_{amb} = 25 °C, unless otherwise specified

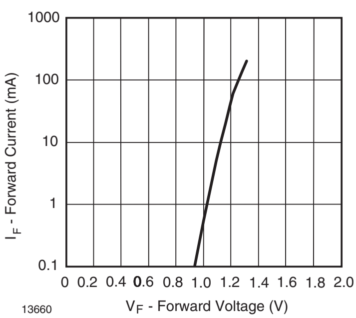


Figure 4. Forward Current vs. Forward Voltage

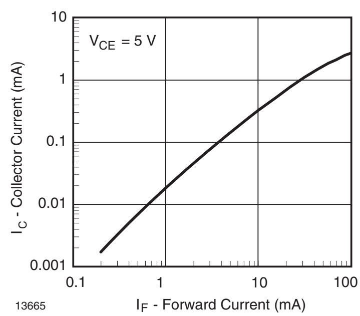


Figure 6. Collector Current vs. Forward Current

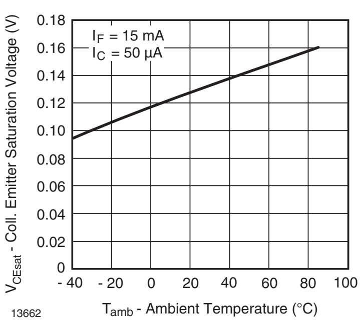


Figure 5. Collector Emitter Saturation Voltage vs. Ambient Temperature

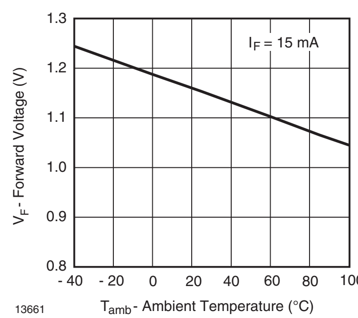


Figure 7. Forward Voltage vs. Ambient Temperature

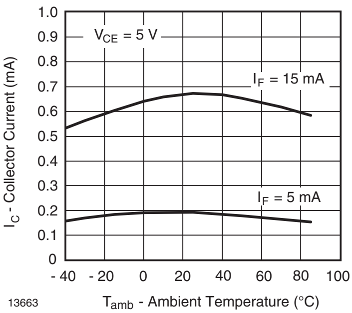


Figure 8. Collector Current vs. Ambient Temperature

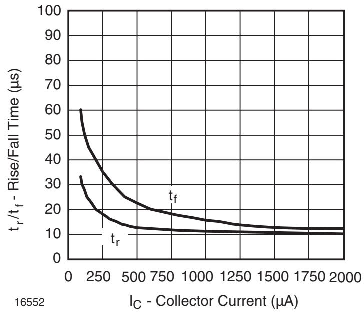


Figure 11. Rise/Fall Time vs. Collector Current

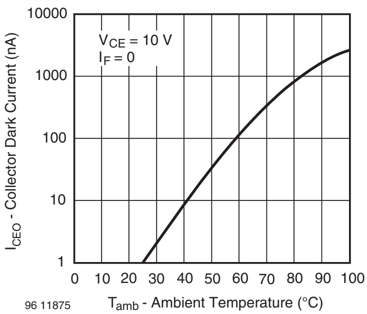


Figure 9. Collector Dark Current vs. Ambient Temperature

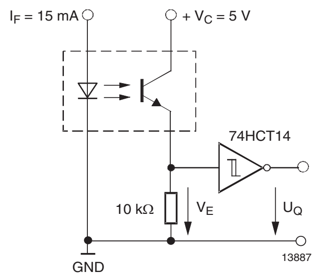


Figure 12. Application example

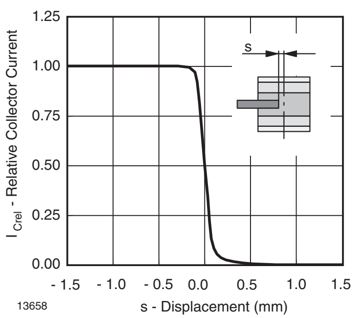


Figure 10. Relative Collector Current vs. Displacement

Reflow Solder Profiles

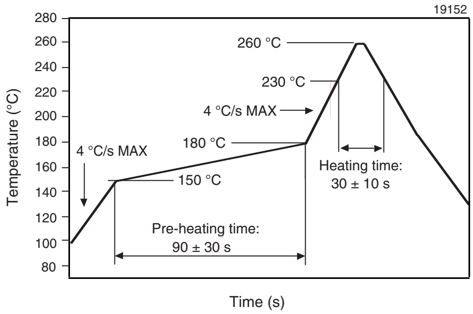


Figure 13. Lead (Pb)-free (Sn) Reflow Solder Profile

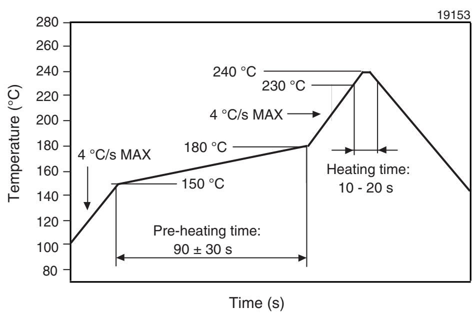


Figure 14. Lead Tin (SnPb) Reflow Solder Profile

Drypack

Devices are packed in moisture barrier bags (MBB) to prevent the products from absorbing moisture during transportation and storage. Each bag contains a desiccant.

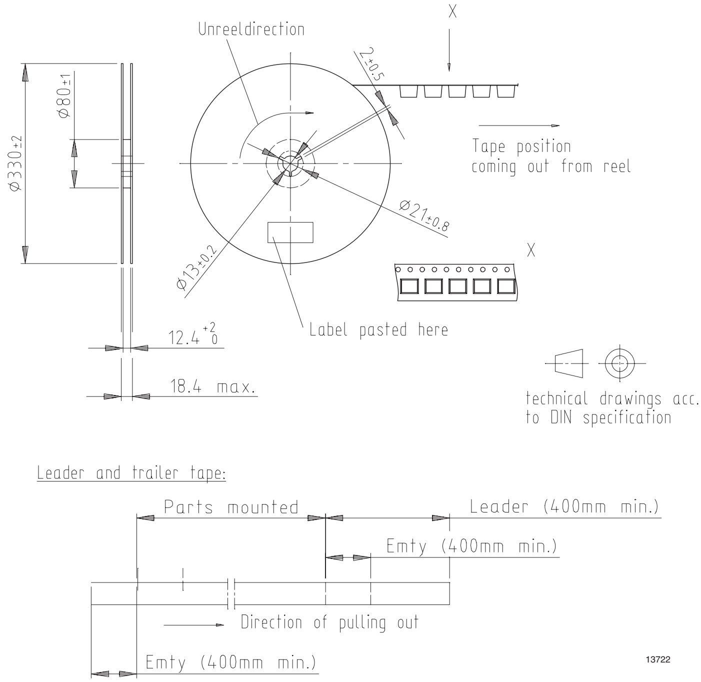
Floor Life

Floor life (time between soldering and removing from MBB) must not exceed the time indicated in J-STD-020. Acc. JEDEC, J-STD-020, TCPT1200 is released to Moisture Sensitivity Level 2, for use of Lead Tin (SnPb) Reflow Solder Profile (figure 14) or Level 3, for use of Lead (Pb)-free (Sn) Reflow Solder Profile (figure 13)
Floor Life: 12 month (level 2) or 168 hours (level 3)
Floor Conditions: T_{amb} < 30 °C, RH < 60 %

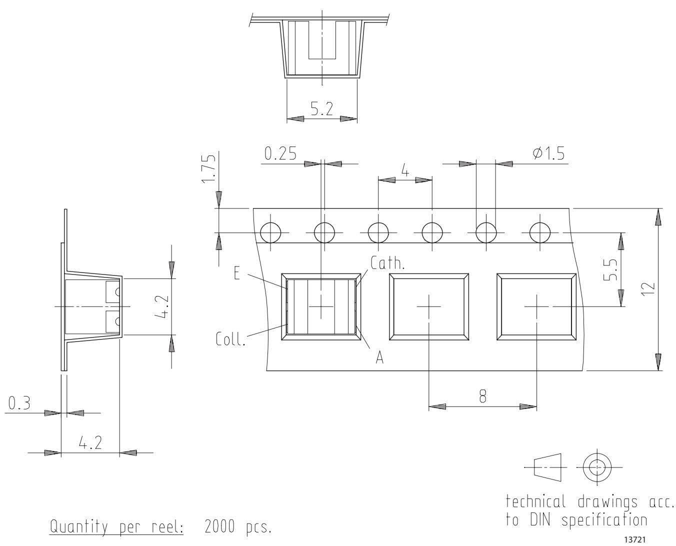
Drying

In case of moisture absorption, devices should be baked before soldering. Conditions see J-STD-020 or Label. Devices taped on reel dry using recommended conditions 192 h at 40 °C (± 5 °C), RH < 5 % or 96 h at 60 °C (± 5 °C), RH < 5 %.

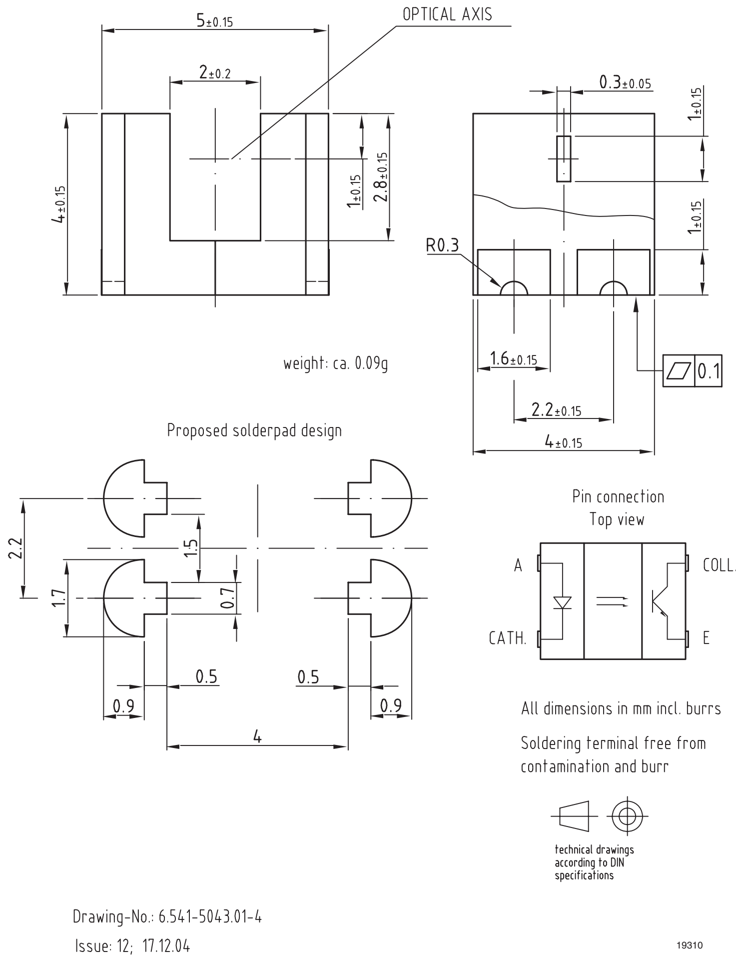
Dimensions of Reel and Tape



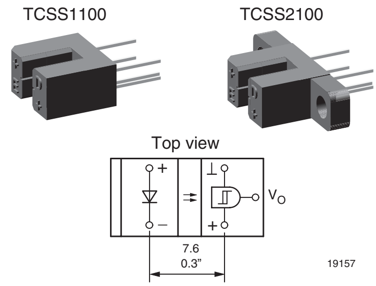
Dimensions of Tape



Package Dimensions



Transmissive Optical Sensor with Schmitt-Trigger Logic Output



Description

The TCSS1100 and TCSS2100 are transmissive sensors which include an infrared emitter and Photo Schmitt-Trigger with digital output interface, located face-to-face on the optical axes, in a leaded package which blocks visible light.

Features

- Package type: Leaded
- Detector type: Photo Schmitt-Trigger
- Dimensions TCSS2100:
  L 24.5 mm x W 6 mm x H 10.8 mm
- Dimensions TCSS1100:
  L 11.9 mm x W 6 mm x H 10.8 mm
- Gap: 3.1 mm
- Aperture: 1 mm
- Typical output current under test: I_C = 16 mA
- Output voltage level is LOW, if I_R beam is not interrupted
- Output device TTL compliant, open collector
- Daylight blocking filter
- Emitter wavelength: 950 nm
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC
- Minimum order quantity: 1020 pcs, 85 pcs/bulk

Applications

- Detection of opaque material, documents etc.
- Paper position sensor in copy machines
- Position sensor for shaft encoder

Handling Precaution

Connect a capacitor of more than 100 nF between V_{S1} and ground in order to stabilize power supply voltage!

Order Instructions

Part Number	Remarks	Resolution, Aperture	Minimum Order Quantity
TCSS1100	Without mounting flange	0.6 mm, 1 mm	1020 pcs, 85 pcs/tube
TCSS2100	With mounting flange	0.6 mm, 1 mm	1020 pcs, 85 pcs/tube

Absolute Maximum Ratings

Coupler

Parameter	Test condition	Symbol	Value	Unit
Total power dissipation	$T_{amb} \leq 25$ °C	P_{tot}	250	mW
Ambient temperature range		T_{amb}	- 25 to + 85	°C
Storage temperature range		T_{stg}	- 40 to + 100	°C
Soldering temperature	Distance to package: 2 mm, $t \leq 5$ s	T_{sd}	260	°C

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Rev. 1.7, 21-Aug-06

Input (Emitter)

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_R	6	V
Forward current		I_F	60	mA
Forward surge current	$t_p \leq 10$ µs	I_{FSM}	3	A
Power dissipation	$T_{amb} \leq 25$ °C	P_V	100	mW
Junction temperature		T_j	100	°C

Output (Detector)

Parameter	Test condition	Symbol	Value	Unit
Supply voltages		V_{S1}	6.5	V
		V_{S2}	18	V
Output current		I_O	20	mA
Power dissipation	$T_{amb} \leq 25$ °C	P_V	250	mW
Junction temperature		T_j	100	°C

Electrical Characteristics

Coupler

T_{amb} = 25 °C, unless otherwise specified

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Supply current	V_{S1} = 16 V	I_{S1}		3	5	mA
Output current	$V_{S1} = V_{S2}$ = 16 V, I_F = 0	I_{OH}			1	µA
Input threshold current	V_{S1} = 5 V	I_{FT}		5	10	mA
Hysteresis	V_{S1} = 5 V	I_{Foff}/I_{Fon}		80		%
Output voltage	I_{OL} = 16 mA, $I_F \geq I_{TF}$, V_{S1} = 5 V	V_{OL}		0.15	0.4	V
Switching frequency	I_F = 3x I_{FT}, $V_{S1} = V_{S2}$ = 5 V, R_L = 1 kΩ	f_{sw}		200		kHz

Input (Emitter)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	I_F = 50 mA	V_F		1.25	1.6	V
Junction capacitance	V_R = 0, f = 1 MHz	C_j		50		pF

Output (Detector)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Supply voltage range		V_{S1}	4.75		5.25	V
		V_{S2}	4.0		16	V

Switching Characteristics

T_{amb} = 25 °C, unless otherwise specified

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Rise time	$V_{S1} = V_{S2}$ = 5 V, $I_F = 3 \times I_{FT}$, R_L = 1 kΩ (see figure 1)	t_r		50.0		ns
Turn-on time	$V_{S1} = V_{S2}$ = 5 V, $I_F = 3 \times I_{FT}$, R_L = 1 kΩ (see figure 1)	t_{on}		1.0		µs
Fall time	$V_{S1} = V_{S2}$ = 5 V, $I_F = 3 \times I_{FT}$, R_L = 1 kΩ (see figure 1)	t_f		20.0		ns
Turn-off time	$V_{S1} = V_{S2}$ = 5 V, $I_F = 3 \times I_{FT}$, R_L = 1 kΩ (see figure 1)	t_{off}		3.0		µs

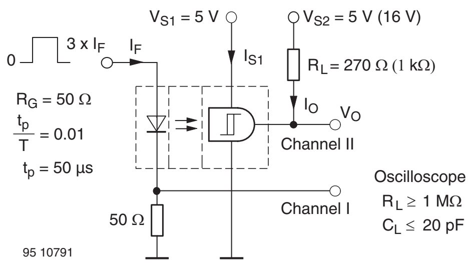


Figure 1. Test circuit for: t_r, t_{on}, t_f, t_{off}

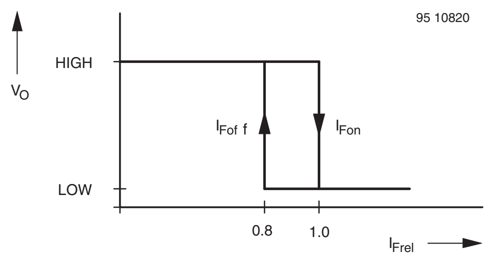


Figure 3. Hysteresis

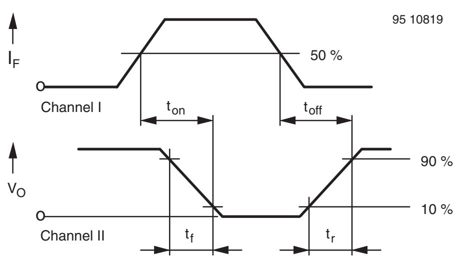


Figure 2. Pulse Diagram

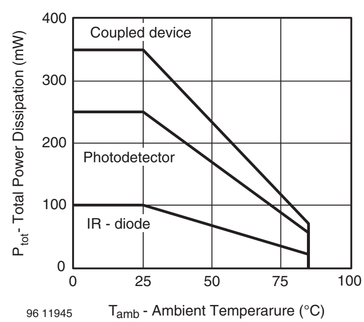


Figure 4. Power Dissipation Limit vs. Ambient Temperature

Typical Characteristics

T_{amb} = 25 °C, unless otherwise specified

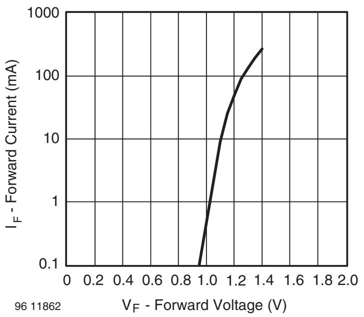


Figure 5. Forward Current vs. Forward Voltage

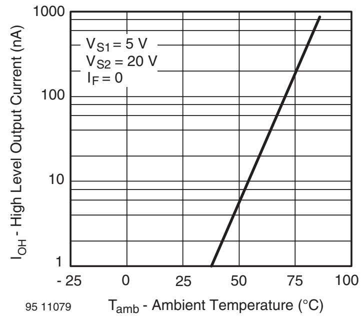


Figure 8. High Level Output Current vs. Ambient Temperature

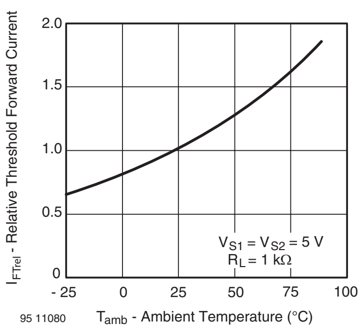


Figure 6. Relative Threshold Forward Current vs. Ambient Temperature

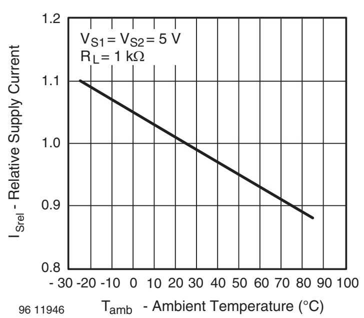
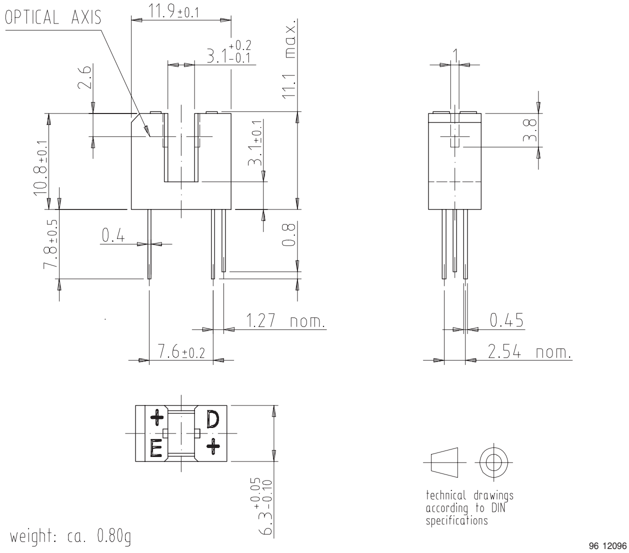
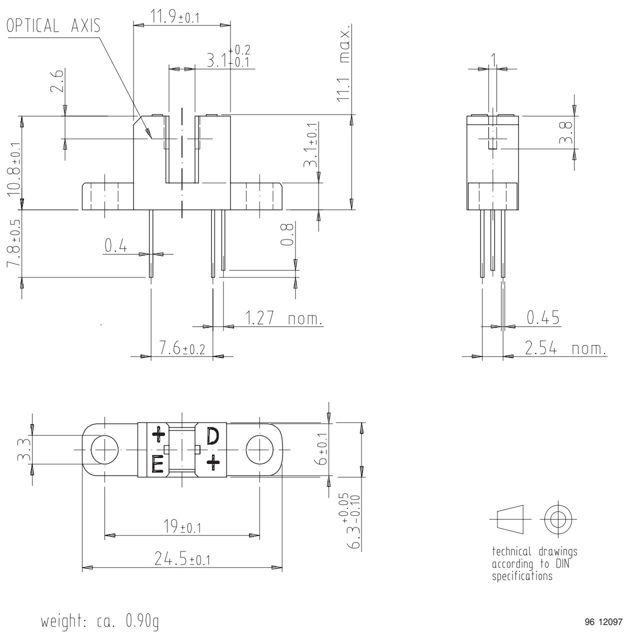


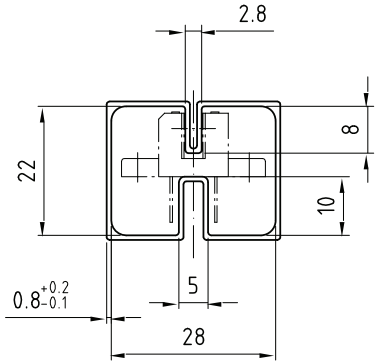
Figure 7. Rel. Supply Current vs. Ambient Temperature

Package Dimensions in mm





Tube Dimensions



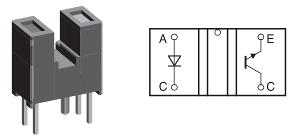
With rubber stopper
Tolerance: ±0.5mm
Length: 575±1mm
All dimensions in mm

Drawing-No.: 9.700-5100.01-4
Issue: 1; 25.02.00
20252

Transmissive Optical Sensor with Phototransistor Output

Description

The TCST1030 and TCST1030L are transmissive sensors that include an infrared emitter and phototransistor, located face-to-face on the optical axes in a leaded package which blocks visible light. TCST1030L is the long lead version.



19171

Features

- Package type: Leaded
- Detector type: Phototransistor
- Dimensions:
  L 8.3 mm x W 4.7 mm x H 8.15 mm
- Gap: 3 mm
- Aperture: none
- Typical output current under test: I_C = 2.4 mA
- Daylight blocking filter
- Emitter wavelength: 950 nm
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC

Pb
Pb-free

e4

Applications

- Optical switch
- Shaft encoder
- Detection of opaque material such as paper
- Detection of magnetic tapes

Order Instructions

Part Number	Remarks	Minimum Order Quantity
TCST1030	3.4 mm lead length	5200 pcs, 65 pcs/tube
TCST1030L	16 mm lead length	2600 pcs, 65 pcs/tube

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Value	Unit
Total power dissipation	$T_{amb} \le 25$ °C	P_{tot}	250	mW
Operation temperature range		T_{amb}	- 25 to + 85	°C
Storage temperature range		T_{stg}	- 25 to + 100	°C
Soldering temperature	1.6 mm from case, t ≤ 10 s	T_{sd}	260	°C

Input (Emitter)

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_R	6	V
Forward current		I_F	60	mA
Forward surge current	$t_p \le 10$ µs	I_{FSM}	3	A
Power dissipation	$T_{amb} \le 25$ °C	P_V	100	mW
Junction temperature		T_j	100	°C

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Rev. 1.6, 16-Aug-06

Output (Detector)

Parameter	Test condition	Symbol	Value	Unit
Collector emitter voltage		V_{CEO}	70	V
Emitter collector voltage		V_{ECO}	7	V
Collector current		I_C	100	mA
Power dissipation	$T_{amb} \leq 25$ °C	P_V	150	mW
Junction temperature		T_j	100	°C

Electrical Characteristics

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector current	V_{CE} = 5 V, I_F = 10 mA	I_C	1.2	2.4		mA
Collector emitter saturation voltage	I_F = 10 mA, I_C = 1 mA	V_{CEsat}			0.8	V

Input (Emitter)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	I_F = 60 mA	V_F		1.25	1.5	V
Junction capacitance	V_R = 0, f = 1 MHz	C_j		50		pF

Output (Detector)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector emitter voltage	I_C = 1 mA	V_{CEO}	70			V
Emitter collector voltage	I_E = 10 μA	V_{ECO}	7			V
Collector dark current	V_{CE} = 25 V, I_F = 0, E = 0	I_{CEO}		10	100	nA

Switching Characteristics

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Turn-on time	I_C = 1 mA, V_{CE} = 5 V, R_L = 100 Ω (see figure 1)	t_{on}		15.0		μs
Turn-off time	I_C = 1 mA, V_{CE} = 5 V, R_L = 100 Ω (see figure 1)	f_{off}		10.0		μs

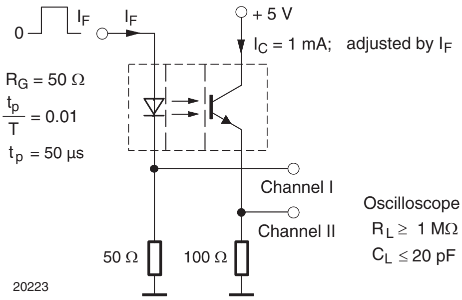


Figure 1. Test Circuit for t_{on} and t_{off}

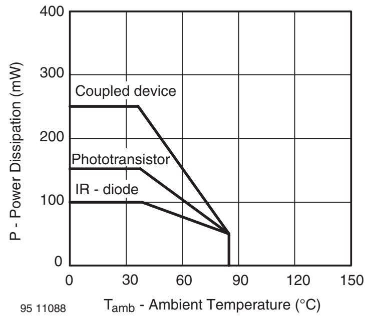


Figure 3. Power Dissipation Limit vs. Ambient Temperature

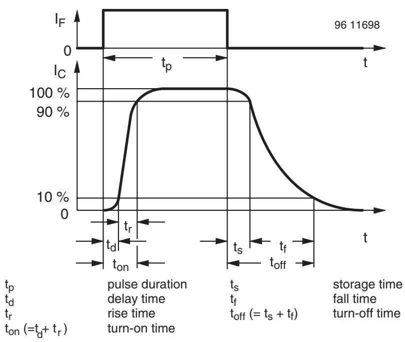


Figure 2. Switching Times

Typical Characteristics

T_{amb} = 25 °C, unless otherwise specified

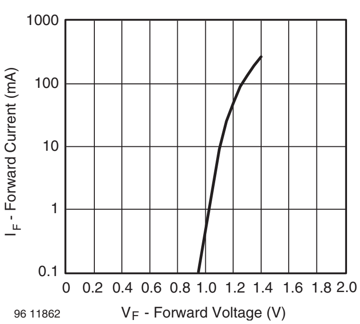


Figure 4. Forward Current vs. Forward Voltage

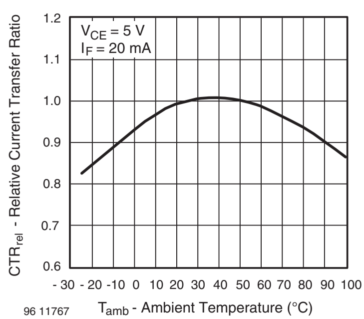


Figure 5. Relative Current Transfer Ratio vs. Ambient Temperature

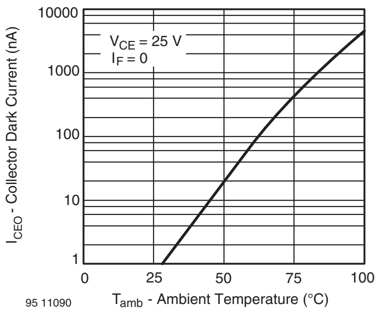


Figure 6. Collector Dark Current vs. Ambient Temperature

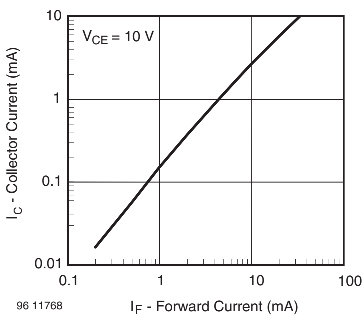


Figure 7. Collector Current vs. Forward Current

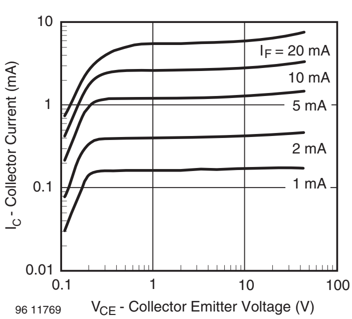


Figure 8. Collector Current vs. Collector Emitter Voltage

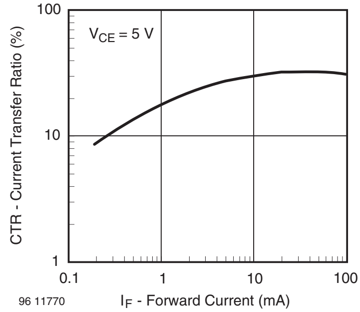


Figure 9. Current Transfer Ratio vs. Forward Current

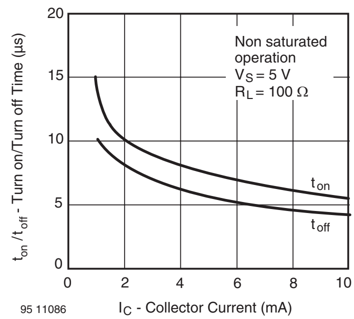


Figure 10. Turn on/off Time vs. Collector Current

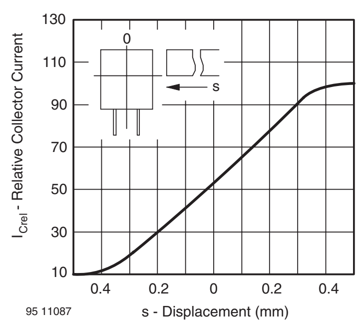
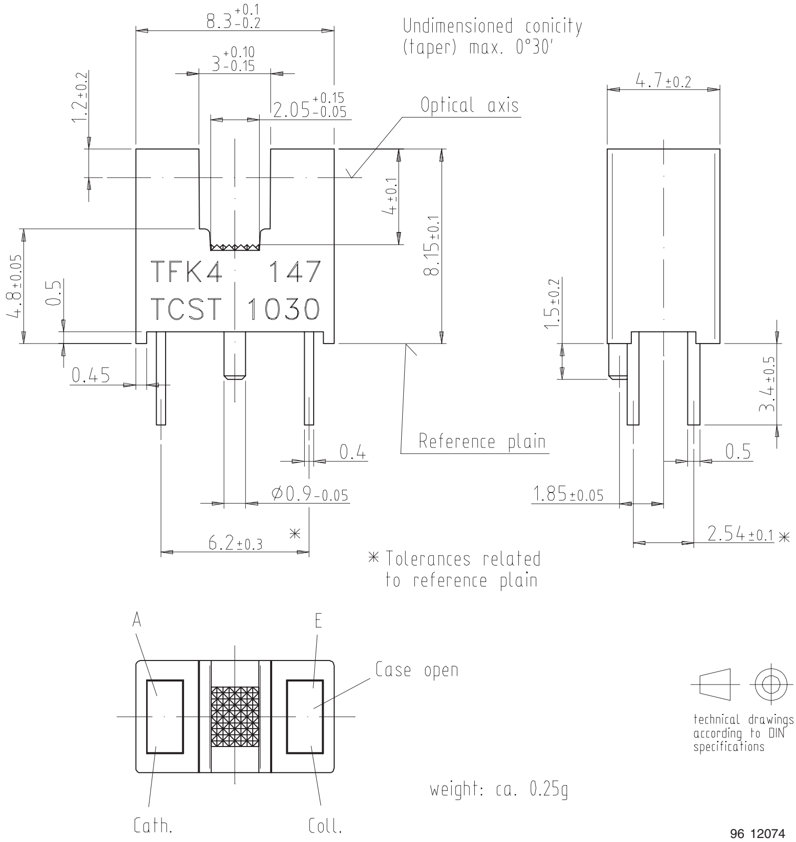
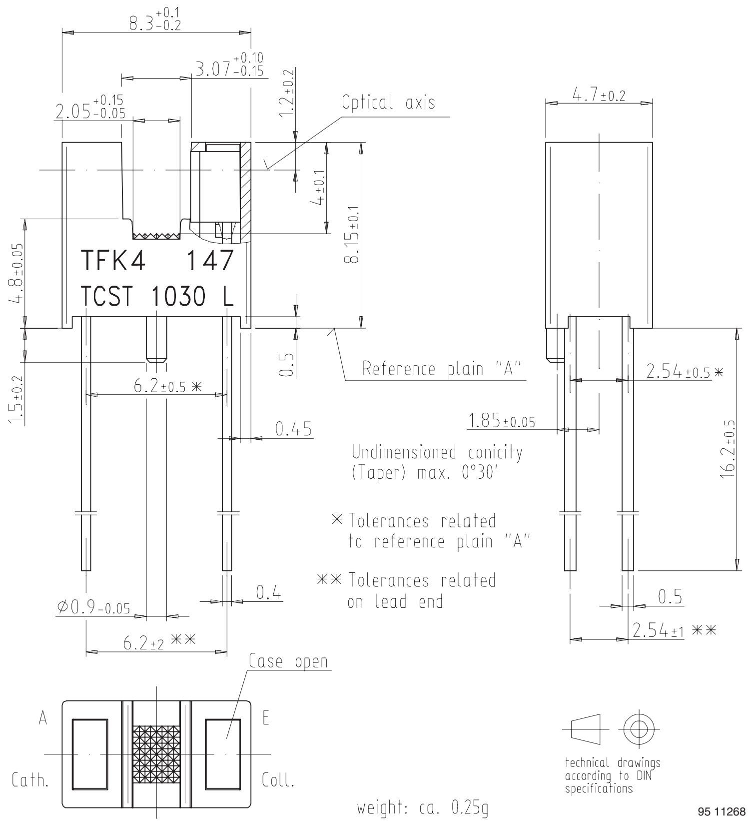


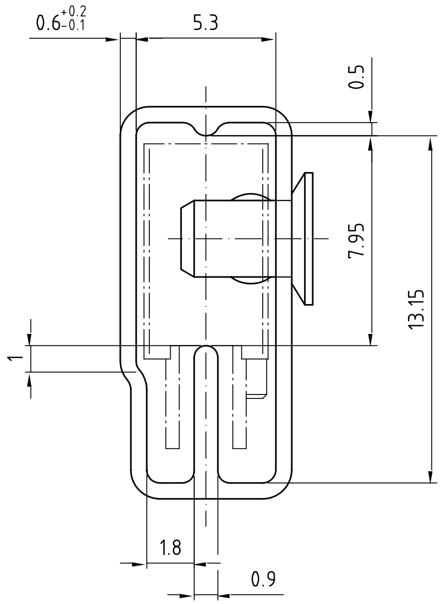
Figure 11. Relative Collector Current vs. Displacement

Package Dimensions in mm

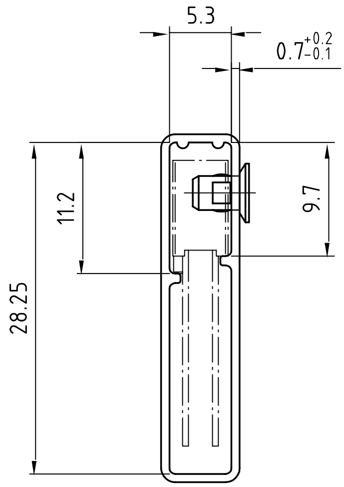



8.3 +0.1 -0.2
3.07 +0.10 -0.15
2.05 +0.15 -0.05
1.2±0.2
Optical axis
4.7±0.2
4±0.1
8.15±0.1
4.8±0.05
TFK4 147
TCST 1030 L
0.5
1.5±0.2
Reference plain "A"
6.2±0.5 *
2.54±0.5 *
1.85±0.05
0.45
16.2±0.5
Undimensioned conicity
(Taper) max. 0°30'
* Tolerances related
to reference plain "A"
** Tolerances related
on lead end
0.4
0.5
⌀0.9-0.05
2.54±1 **
6.2±2 **
Case open
A
E
Cath.
Coll.
technical drawings
according to DIN
specifications
weight: ca. 0.25g
95 11268

Tube Dimensions in mm



Drawing-No.: 9.700-5140.01-4
Issue: 1; 25.02.00
20253



With stopper pins
Tolerance: ±0.5mm
Length: 575±1mm

All dimensions in mm

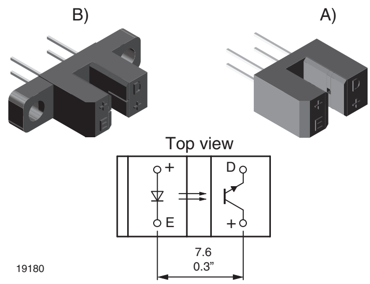
Drawing-No.: 9.700-5205.01-4
Issue: 1; 25.02.00

20254

Transmissive Optical Sensor with Phototransistor Output

Description

The TCST1103, 1202, 1300, 2103, 2202 and 2300 are transmissive sensors that include an infrared emitter and phototransistor, located face-to-face on the optical axes in a leaded package which blocks visible light. These part numbers include options for aperture width and mounting flanges.



Features

- Package type: Leaded
- Detector type: Phototransistor
- Dimensions package A:
  L 11.9 mm x W 6.3 mm x H 10.8 mm
- Dimensions package B:
  L 24.5 mm x W 6.3 mm x H 10.8 mm
- Gap: 3.1 mm
- Typical output current under test: I_C = 4 mA (TCST1103/2103)
- Typical output current under test: I_C = 2 mA (TCST1202/2202)
- Typical output current under test: I_C = 0.5 mA (TCST1300/2300)
- Daylight blocking filter
- Emitter wavelength: 950 nm
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC

Applications

- Optical switch
- Photo interrupter
- Counter
- Encoder

Order Instructions

Part Number	Remarks	Resolution, Aperture	Minimum Order Quantity
TCST1103	Without mounting flange[A)]	0.6 mm, 1 mm	1020 pcs, 85 pcs/tube
TCST1202	Without mounting flange[A)]	0.4 mm, 0.5 mm	1020 pcs, 85 pcs/tube
TCST1300	Without mounting flange[A)]	0.2 mm, 0.25 mm	1020 pcs, 85 pcs/tube
TCST2103	With mounting flange[B)]	0.6 mm, 1 mm	1020 pcs, 85 pcs/tube
TCST2202	With mounting flange[B)]	0.4 mm, 0.5 mm	1020 pcs, 85 pcs/tube
TCST2300	With mounting flange[B)]	0.2 mm, 0.25 mm	1020 pcs, 85 pcs/tube

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Value	Unit
Total power dissipation	$T_{amb} \leq 25$ °C	P_{tot}	250	mW
Operating temperature range		T_{amb}	- 55 to + 85	°C
Storage temperature range		T_{stg}	- 55 to + 100	°C
Soldering temperature	Distance to package: 2 mm; $t \leq 5$ s	T_{sd}	260	°C

Input (Emitter)

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_R	6	V
Forward current		I_F	60	mA
Forward surge current	$t_p \leq 10$ µs	I_{FSM}	3	A
Power dissipation	$T_{amb} \leq 25$°C	P_V	100	mW
Junction temperature		T_j	100	°C

Output (Detector)

Parameter	Test condition	Symbol	Value	Unit
Collector emitter voltage		V_{CEO}	70	V
Emitter collector voltage		V_{ECO}	7	V
Collector current		I_C	100	mA
Collector peak current	$t_p/T = 0.5$, $t_p \leq 10$ ms	I_{CM}	200	mA
Power dissipation	$T_{amb} \leq 25$°C	P_V	150	mW
Junction temperature		T_j	100	°C

Electrical Characteristics

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Part	Symbol	Min	Typ.	Max	Unit
Current Transfer Ratio	V_{CE} = 5 V, I_F = 20 mA	TCST1103, TCST2103	CTR	10	20		%
		TCST1202, TCST2202	CTR	5	10		%
		TCST1300, TCST2300	CTR	1.25	2.5		%
Collector current	V_{CE} = 5 V, I_F = 20 mA	TCST1103, TCST2103	I_C	2	4		mA
		TCST1202, TCST2202	I_C	1	2		mA
		TCST1300, TCST2300	I_C	0.25	0.5		mA
Collector emitter saturation voltage	I_F = 20 mA, I_C = 1 mA	TCST1103, TCST2103	V_{CEsat}			0.4	V
	I_F = 20 mA, I_C = 0.5 mA	TCST1202, TCST2202	V_{CEsat}			0.4	V
	I_F = 20 mA, I_C = 0.1 mA	TCST1300, TCST2300	V_{CEsat}			0.4	V
Resolution, path of the shutter crossing the radiant sensitive zone	I_{Crel} = 10 to 90 %	TCST1103, TCST2103	s		0.6		mm
		TCST1202, TCST2202	s		0.4		mm
		TCST1300, TCST2300	s		0.2		mm

Input (Emitter)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	I_F = 60 mA	V_F		1.25	1.6	V
Junction capacitance	V_R = 0, f = 1 MHz	C_j		50		pF

Output (Detector)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector emitter voltage	I_C = 1 mA	V_{CEO}	70			V
Emitter collector voltage	I_E = 10 μA	V_{ECO}	7			V
Collector dark current	V_{CE} = 25 V, I_F = 0, E = 0	I_{CEO}			100	nA

Switching Characteristics

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Turn-on time	V_S = 5 V, I_C = 2 mA, R_L = 100 Ω (see figure 1)	t_{on}		10.0		μs
Turn-off time	V_S = 5 V, I_C = 2 mA, R_L = 100 Ω (see figure 1)	t_{off}		8.0		μs

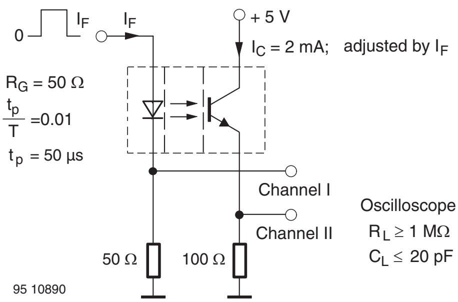


Figure 1. Test circuit for t_{on} and t_{off}

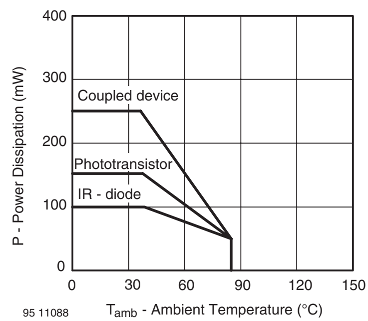


Figure 3. Power Dissipation Limit vs. Ambient Temperature

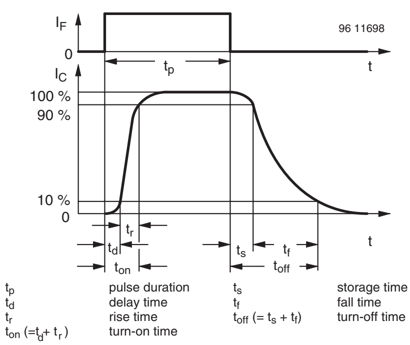


Figure 2. Switching Times

Typical Characteristics

T_{amb} = 25 °C, unless otherwise specified

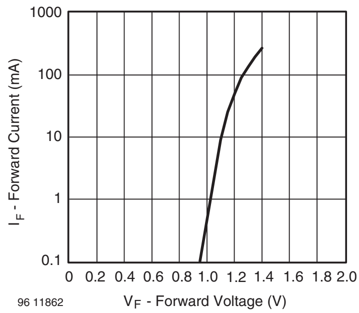


Figure 4. Forward Current vs. Forward Voltage

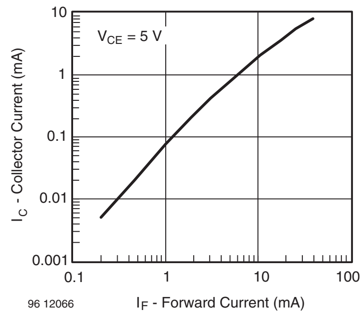


Figure 7. Collector Current vs. Forward Current

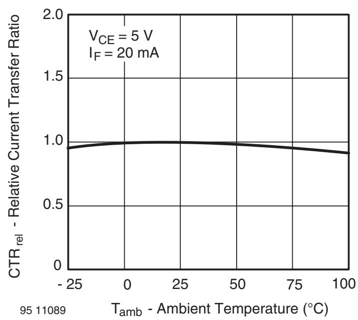


Figure 5. Relative Current Transfer Ratio vs. Ambient Temperature

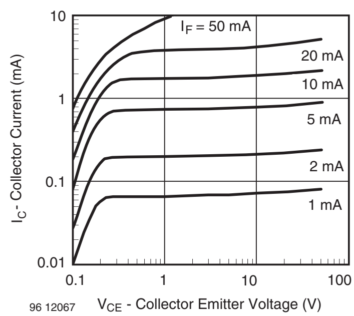


Figure 8. Collector Current vs. Collector Emitter Voltage

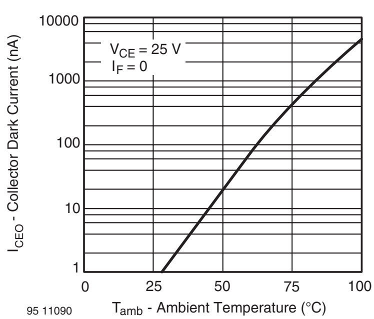


Figure 6. Collector Dark Current vs. Ambient Temperature

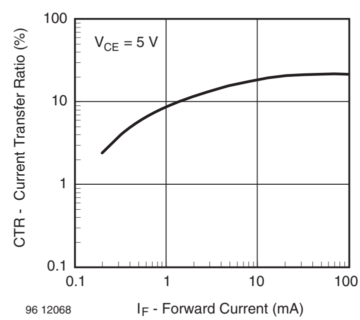


Figure 9. Current Transfer Ratio vs. Forward Current

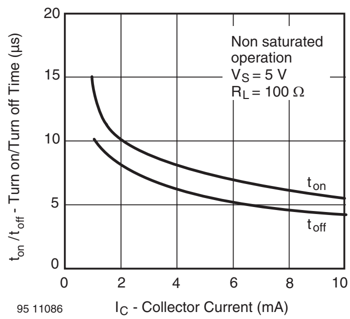


Figure 10. Turn on/off Time vs. Collector Current

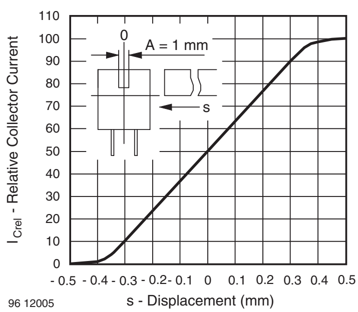


Figure 11. Relative Collector Current vs. Displacement

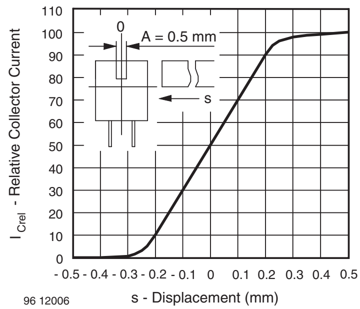


Figure 12. Relative Collector Current vs. Displacement

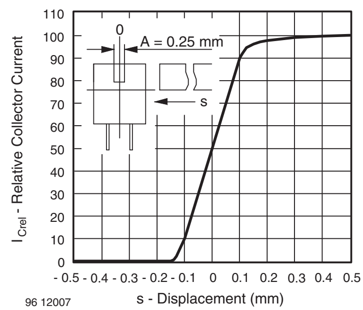
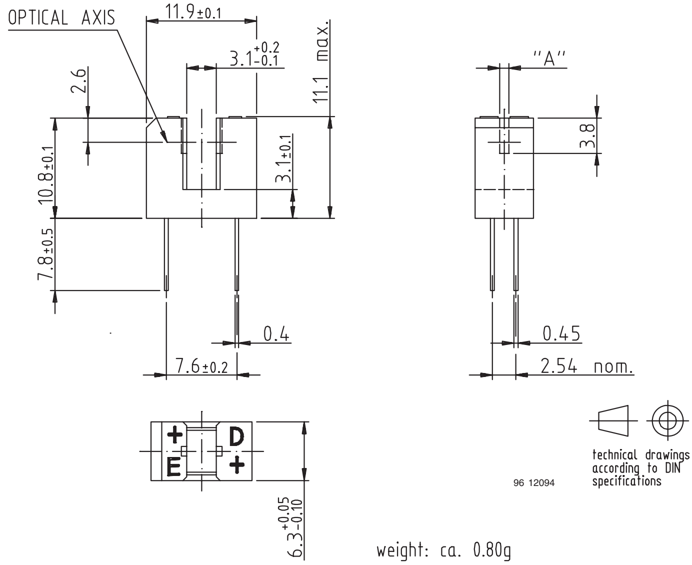
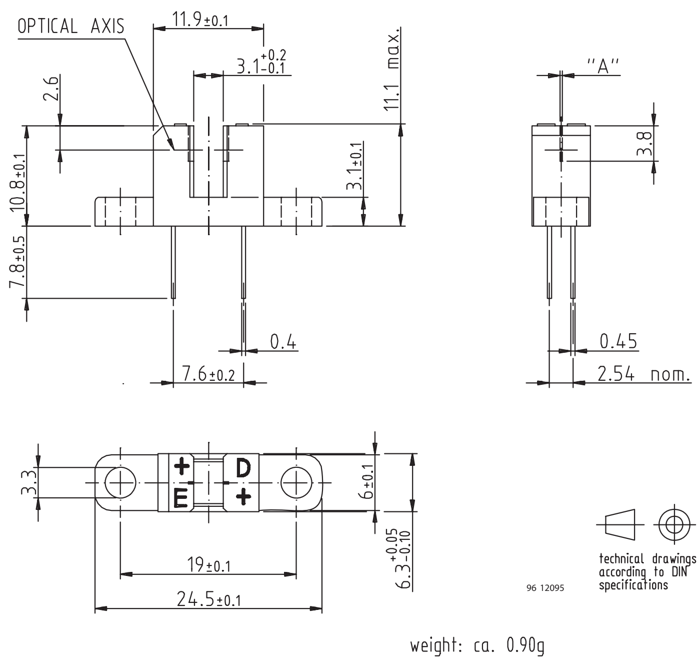


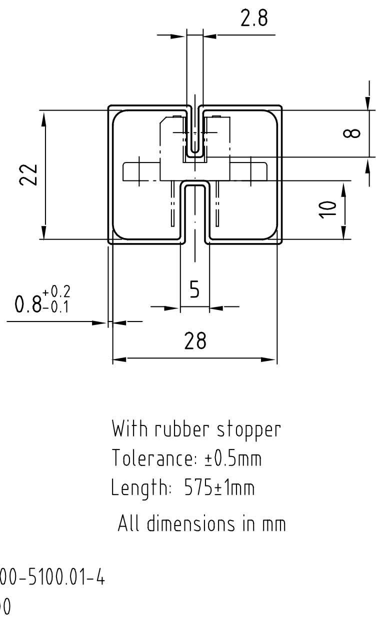
Figure 13. Relative Collector Current vs. Displacement

Package Dimensions in mm





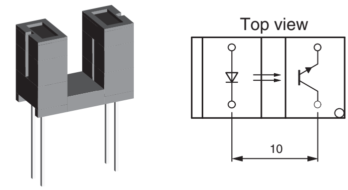
Tube Dimensions



Transmissive Optical Sensor with Phototransistor Output

Description

The TCST1210 is a transmissive sensor that includes an infrared emitter and a phototransistor, located face-to-face on the optical axes in a leaded package which blocks visible light.



19202

Features

- Package type: Leaded
- Detector type: Phototransistor
- Dimensions:
  L 13 mm x W 6 mm x H 10 mm
- Gap: 5 mm
- Aperture: 0.5 mm
- Typical output current under test: I_C = 2 mA
- Daylight blocking filter
- Emitter wavelength: 950 nm
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC
- Minimum order quantity: 2160 pcs, 90 pcs/tube

Applications

- Optical switch
- Photo interrupter
- Counter
- Encoder

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Value	Unit
Total power dissipation	$T_{amb} \leq 25$ °C	P_{tot}	200	mW
Operating temperature range		T_{amb}	- 20 to + 85	°C
Storage temperature range		T_{stg}	- 30 to + 100	°C
Soldering temperature	Distance to package 2 mm, $t \leq 5$ s	T_{sd}	260	°C

Input (Emitter)

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_R	5	V
Forward current		I_F	50	mA
Forward surge current	$t_p \leq 10$ µs	I_{FSM}	1	A
Power dissipation	$T_{amb} \leq 25$ °C	P_V	100	mW
Junction temperature		T_j	100	°C

Output (Detector)

Parameter	Test condition	Symbol	Value	Unit
Collector emitter voltage		V_{CEO}	30	V
Emitter collector voltage		V_{ECO}	5	V
Collector current		I_C	30	mA
Collector peak current	$t_p/T = 0.5$, $t_p \leq 10$ ms	I_{CM}	100	mA
Power dissipation	$T_{amb} \leq 25$ °C	P_V	100	mW
Junction temperature		T_j	100	°C

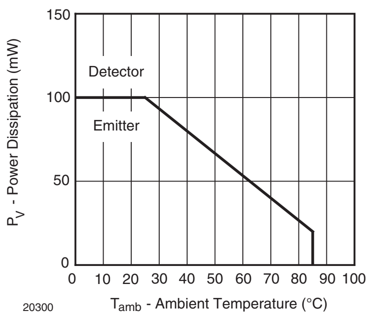


Figure 1. Power Dissipation Limit vs. Ambient Temperature

Electrical Characteristics

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Current Transfer Ratio	V_{CE} = 5 V, I_F = 20 mA	CTR	2.5	10		%
Collector current	V_{CE} = 5 V, I_F = 20 mA	I_C	0.5	2		mA

Input (Emitter)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	I_F = 20 mA	V_F		1.25	1.6	V
Reverse voltage	I_R = 10 µA	V_R	5			V
Junction capacitance	V_R = 0, f = 1 MHz	C_j		50		pF

Output (Detector)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector emitter voltage	I_C = 1 mA	V_{CEO}	30			V
Emitter collector voltage	I_E = 10 µA	V_{ECO}	5			V
Collector dark current	V_{CE} = 10 V, I_F = 0, E = 0	I_{CEO}			100	nA

Switching Characteristics

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Rise time	V_S = 5 V, I_C = 100 µA, R_L = 1 kΩ (see figure 2)	t_r		20.0		µs
Fall time	V_S = 5 V, I_C = 100 µA, R_L = 1 kΩ (see figure 2)	t_f		20.0		µs

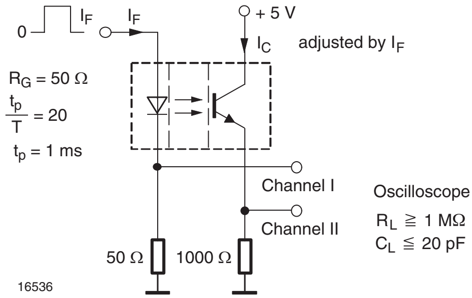


Figure 2. Test Circuit

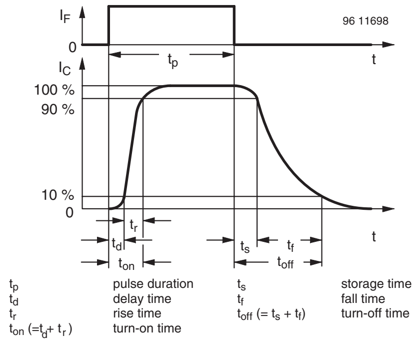


Figure 3. Switching Times

Typical Characteristics

T_{amb} = 25 °C, unless otherwise specified

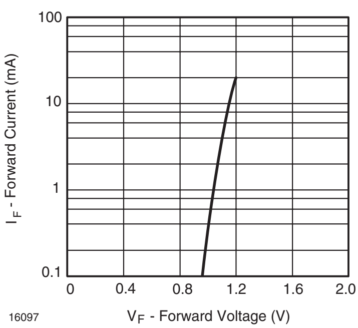


Figure 4. Forward Current vs. Forward Voltage

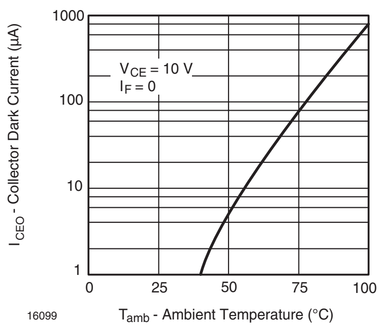


Figure 6. Collector Dark Current vs. Ambient Temperature

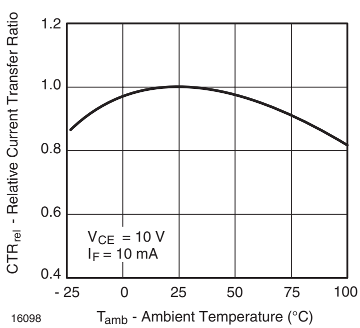


Figure 5. Relative Current Transfer Ratio vs. Ambient Temperature

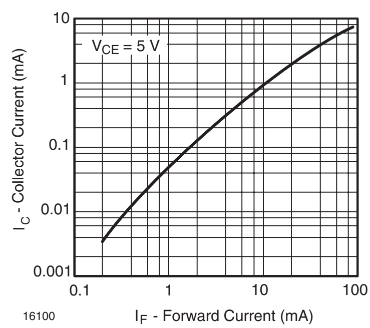


Figure 7. Collector Current vs. Forward Current

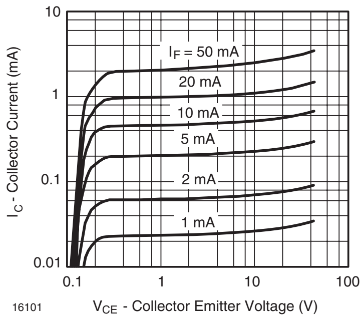


Figure 8. Collector Current vs. Collector Emitter Voltage

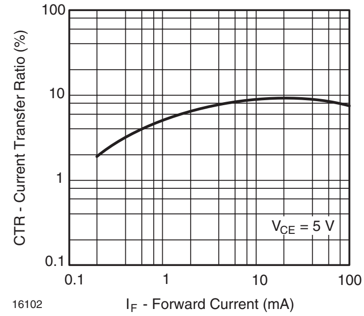
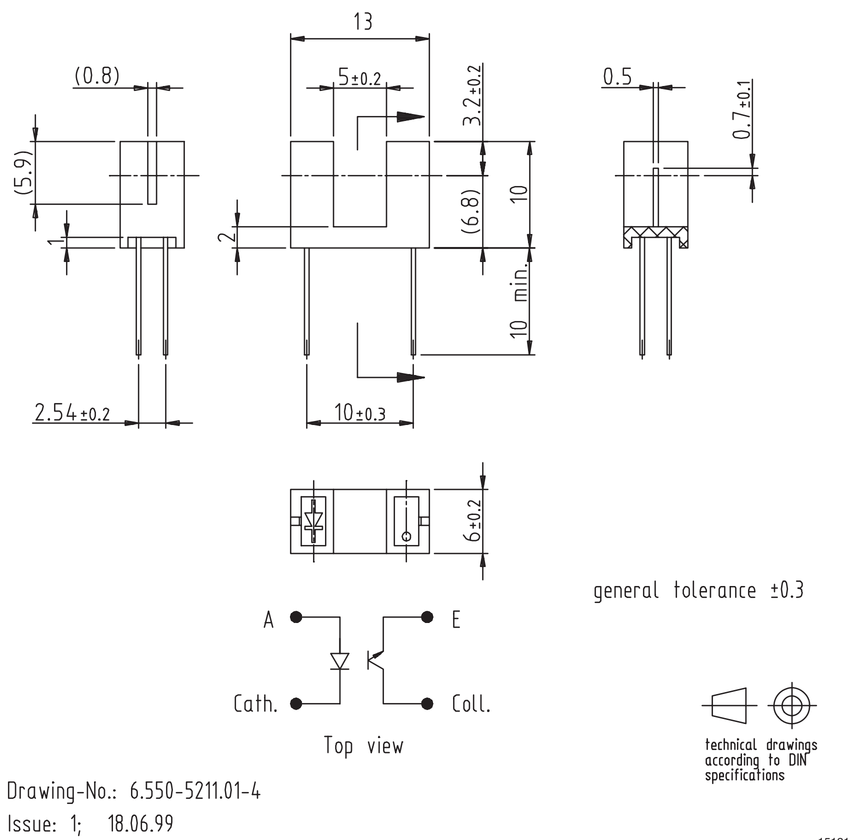
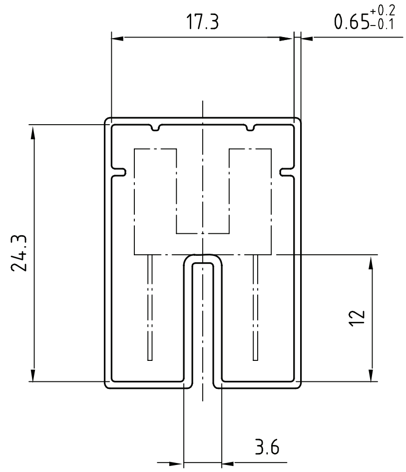


Figure 9. Current Transfer Ratio vs. Forward Current

Package Dimensions in mm



Tube Dimensions



With rubber stopper
Tolerance: ±0.5mm
Length: 575±1mm

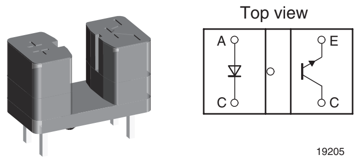
All dimensions in mm

Drawing-No.: 9.700-5244.01-4
Issue: 1; 25.02.00
20255

Transmissive Optical Sensor with Phototransistor Output

Description

The TCST1230 is a transmissive sensor that includes an infrared emitter and phototransistor, located face-to-face on the optical axes in a leaded package which blocks visible light.



Features

- Package type: Leaded
- Detector type: Phototransistor
- Dimensions:
  L 9.2 mm x W 4.8 mm x H 5.4 mm
- Gap: 2.8 mm
- Aperture: 0.5 mm
- Typical output current under test: I_C = 2 mA
- Daylight blocking filter
- Emitter wavelength: 950 nm
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC
- Minimum order quantity: 4800 pcs, 60 pcs/tube

Applications

- Optical switch
- Shaft encoder
- Detection of opaque material such as paper
- Detection of magnetic tapes

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Value	Unit
Total power dissipation	$T_{amb} \leq 25$ °C	P_{tot}	250	mW
Operation temperature range		T_{amb}	- 25 to + 85	°C
Storage temperature range		T_{stg}	- 40 to + 100	°C
Soldering temperature	Distance to package 1.6 mm, $t \leq 5$ s	T_{sd}	260	°C

Input (Emitter)

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_R	6	V
Forward current		I_F	60	mA
Forward surge current	$t_p \leq 10$ µA	I_{FSM}	3	A
Power dissipation	$T_{amb} \leq 25$ °C	P_V	100	mW
Junction temperature		T_j	100	°C

Document Number 83765
Rev. 1.6, 16-Aug-06

Output (Detector)

Parameter	Test condition	Symbol	Value	Unit
Collector emitter voltage		V_{CEO}	70	V
Emitter collector voltage		V_{ECO}	7	V
Collector current		I_C	100	mA
Power dissipation	$T_{amb} \leq 25$ °C	P_V	150	mW
Junction temperature		T_j	100	°C

Electrical Characteristics

$T_{amb} = 25$ °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector current	$V_{CE} = 10$ V, $I_F = 20$ mA	I_C	0.5		14	mA
Collector emitter saturation voltage	$I_F = 20$ mA, $I_C = 0.2$ mA	V_{CEsat}			0.4	V

Input (Emitter)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	$I_F = 60$ mA	V_F		1.25	1.5	V
Junction capacitance	$V_R = 0$, f = 1 MHz	C_j		50		pF

Output (Detector)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector emittter voltage	$I_C = 1$ mA	V_{CEO}	70			V
Emitter collector voltage	$I_E = 10$ µA	V_{ECO}	7			V
Collector dark current	$V_{CE} = 25$ V, $I_F = 0$, E = 0	I_{CEO}		10	100	nA

Switching Characteristics

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Turn-on time	$I_C = 1$ mA, $V_{CE} = 5$ V, $R_L = 100\ \Omega$ (see figure 1)	t_{on}		15.0		µs
Turn-off time	$I_C = 1$ mA, $V_{CE} = 5$ V, $R_L = 100\ \Omega$ (see figure 1)	t_{off}		10.0		µs

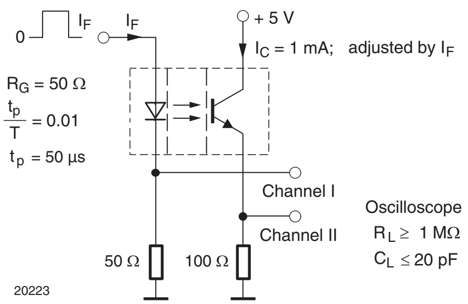


Figure 1. Test Circuit for t_{on} and t_{off}

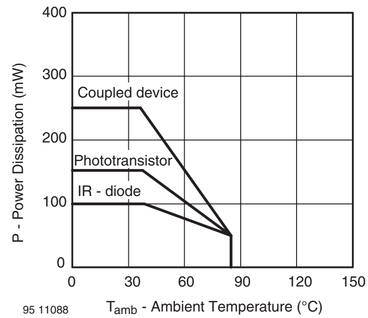


Figure 3. Power Dissipation Limit vs. Ambient Temperature

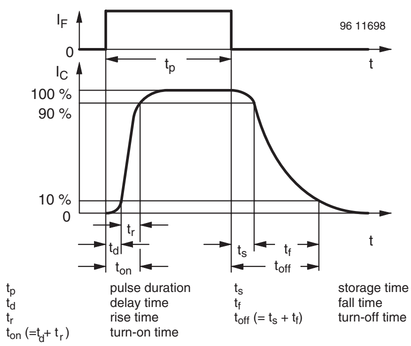


Figure 2. Switching Times

Typical Characteristics

T_{amb} = 25 °C, unless otherwise specified

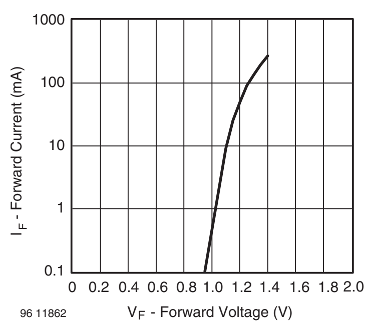


Figure 4. Forward Current vs. Forward Voltage

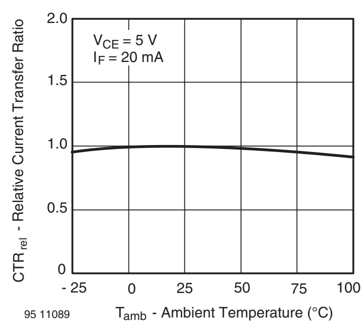


Figure 5. Relative Current Transfer Ratio vs. Ambient Temperature

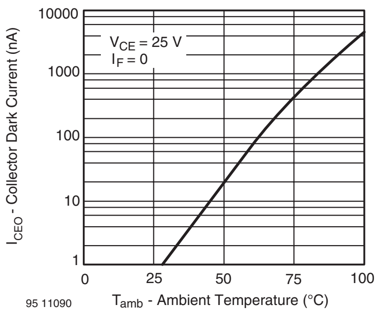


Figure 6. Collector Dark Current vs. Ambient Temperature

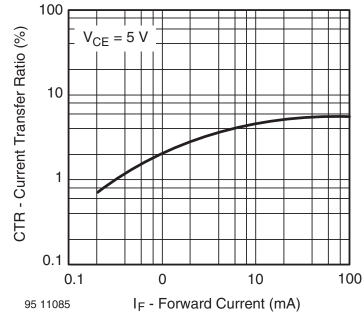


Figure 9. Current Transfer Ratio vs. Forward Current

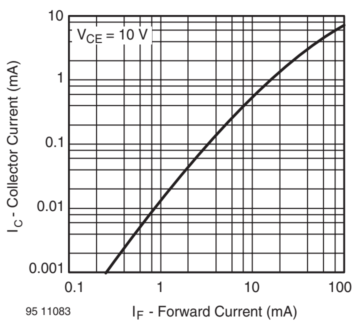


Figure 7. Collector Current vs. Forward Current

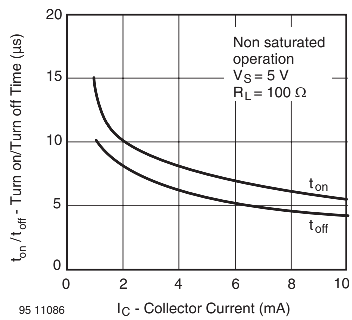


Figure 10. Turn on/off Time vs. Collector Current

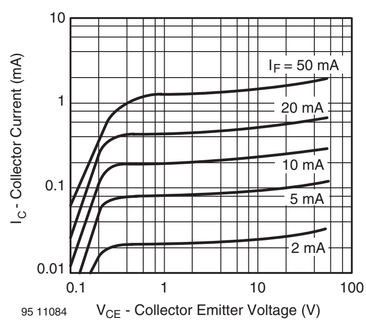


Figure 8. Collector Current vs. Collector Emitter Voltage

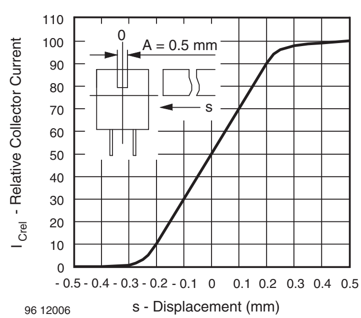
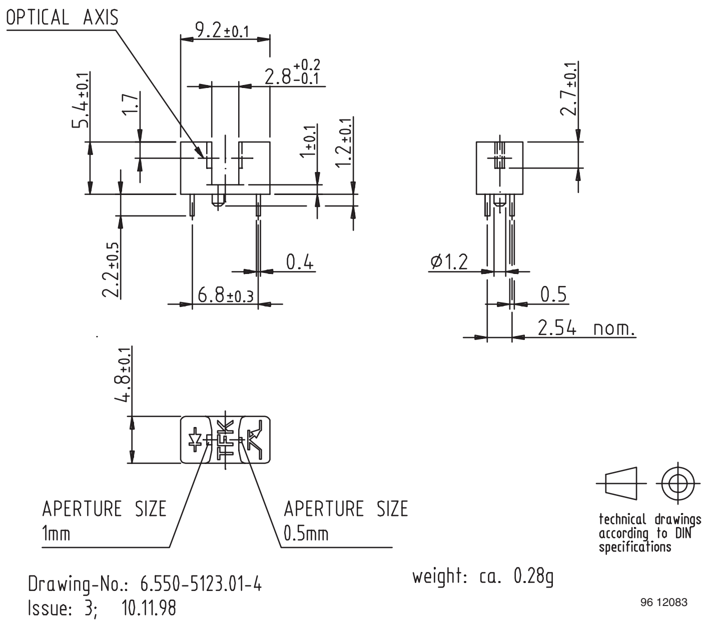
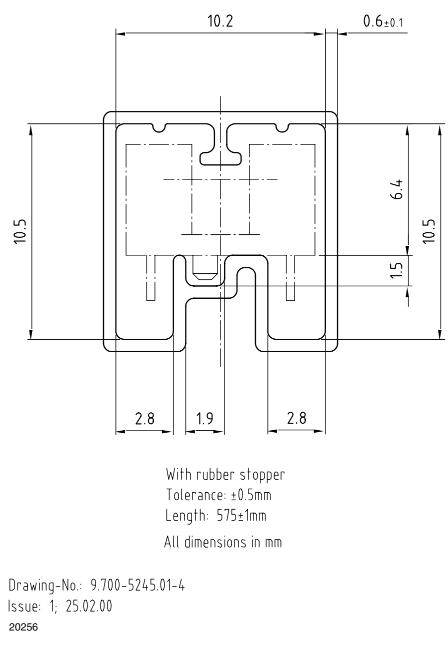


Figure 11. Relative Collector Current vs. Displacement

Package Dimensions in mm



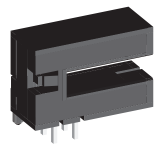
Tube Dimensions



Transmissive Optical Sensor with Phototransistor Output

Description

The TCST5250 is a transmissive sensor that includes an infrared emitter and a phototransistor, located face-to-face on the optical axes in a leaded package which blocks visible light.



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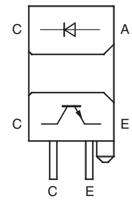


Features

- Package type: Leaded
- Detector type: Phototransistor
- Dimensions:
  L 14.3 mm x W 6 mm x H 9.5 mm
- Gap: 2.7 mm
- Aperture: 0.5 mm
- Typical output current under test: I_C = 1.5 mA
- Daylight blocking filter
- Emitter wavelength: 950 nm
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC
- Minimum order quantity: 4860 pcs, 30 pcs/tube

Pb
Pb-free

e2

Applications

- Optical switch
- Shaft encoder

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Value	Unit
Power dissipation	$T_{amb} \leq 25$ °C	P	250	mW
Operation temperature range		T_{amb}	- 25 to + 85	°C
Storage temperature range		T_{stg}	- 40 to + 100	°C
Soldering temperature	Distance to package 1.6 mm, $t \leq 5$ s	T_{sd}	260	°C

Input (Emitter)

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_R	6	V
Forward current		I_F	60	mA
Forward surge current	$t_p \leq 10$ µs	I_{FSM}	3	A
Power dissipation	$T_{amb} \leq 25$ °C	P_V	100	mW
Junction temperature		T_j	100	°C

Output (Detector)

Parameter	Test condition	Symbol	Value	Unit
Collector emitter voltage		V_{CEO}	70	V
Emitter collector voltage		V_{ECO}	7	V
Collector current		I_C	100	mA
Power dissipation	$T_{amb} \leq 25$ °C	P_V	150	mW
Junction temperature		T_j	100	°C

Electrical Characteristics

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector current	V_{CE} = 10 V, I_F = 20 mA	I_C	0.5	1.5	15	mA
Collector emitter saturation voltage	I_F = 20 mA, I_C = 0.2 mA	V_{CEsat}			0.4	V

Input (Emitter)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	I_F = 60 mA	V_F		1.25	1.5	V
Junction capacitance	V_R = 0, f = 1 MHz	C_j		50		pF

Output (Detector)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector emittter voltage	I_C = 1 mA	V_{CEO}	70			V
Emitter collector voltage	I_E = 10 μA	V_{ECO}	7			V
Collector dark current	V_{CE} = 25 V, I_F = 0, E = 0	I_{CEO}		10	100	nA

Switching Characteristics

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Turn-on time	I_C = 1 mA, V_{CE} = 5 V, R_L = 100 Ω (see figure 1)	t_{on}		15.0		μs
Turn-off time	I_C = 1 mA, V_{CE} = 5 V, R_L = 100 Ω (see figure 1)	t_{off}		10.0		μs

Document Number 83787
Rev. 1.4, 16-Aug-06

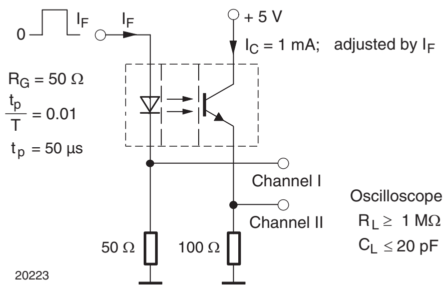


Figure 1. Test Circuit for t_{on} and t_{off}

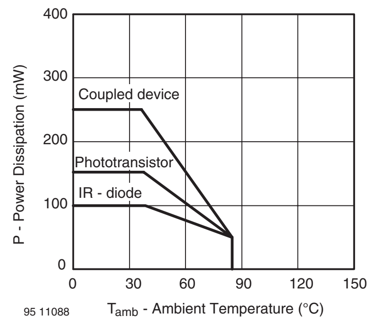


Figure 3. Power Dissipation Limit vs. Ambient Temperature

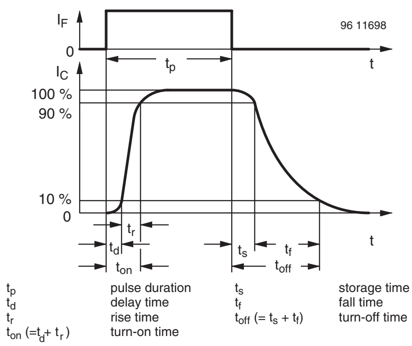


Figure 2. Switching Times

Typical Characteristics

T_{amb} = 25 °C, unless otherwise specified

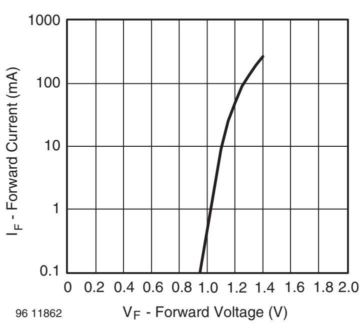


Figure 4. Forward Current vs. Forward Voltage

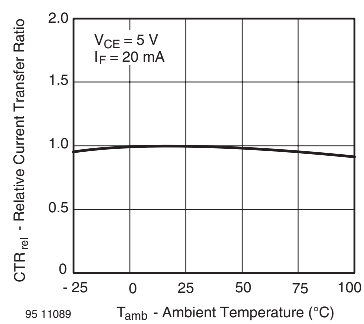


Figure 5. Relative Current Transfer Ratio vs. Ambient Temperature

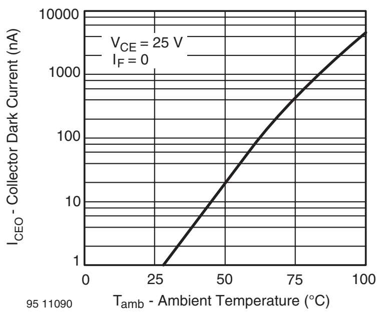


Figure 6. Collector Dark Current vs. Ambient Temperature

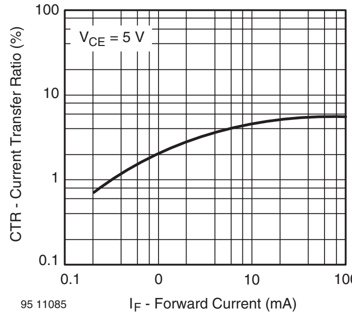


Figure 9. Current Transfer Ratio vs. Forward Current

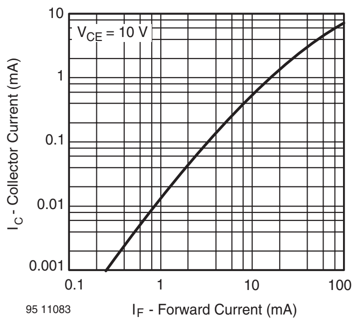


Figure 7. Collector Current vs. Forward Current

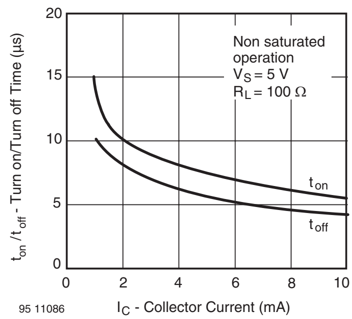


Figure 10. Turn on/off Time vs. Collector Current

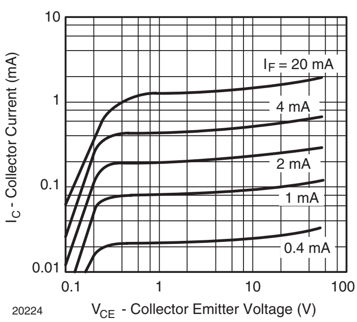


Figure 8. Collector Current vs. Collector Emitter Voltage

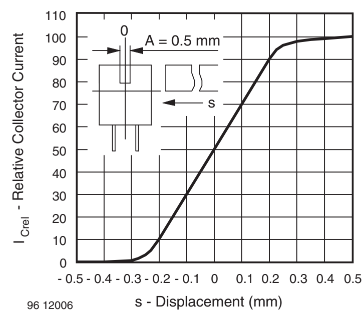
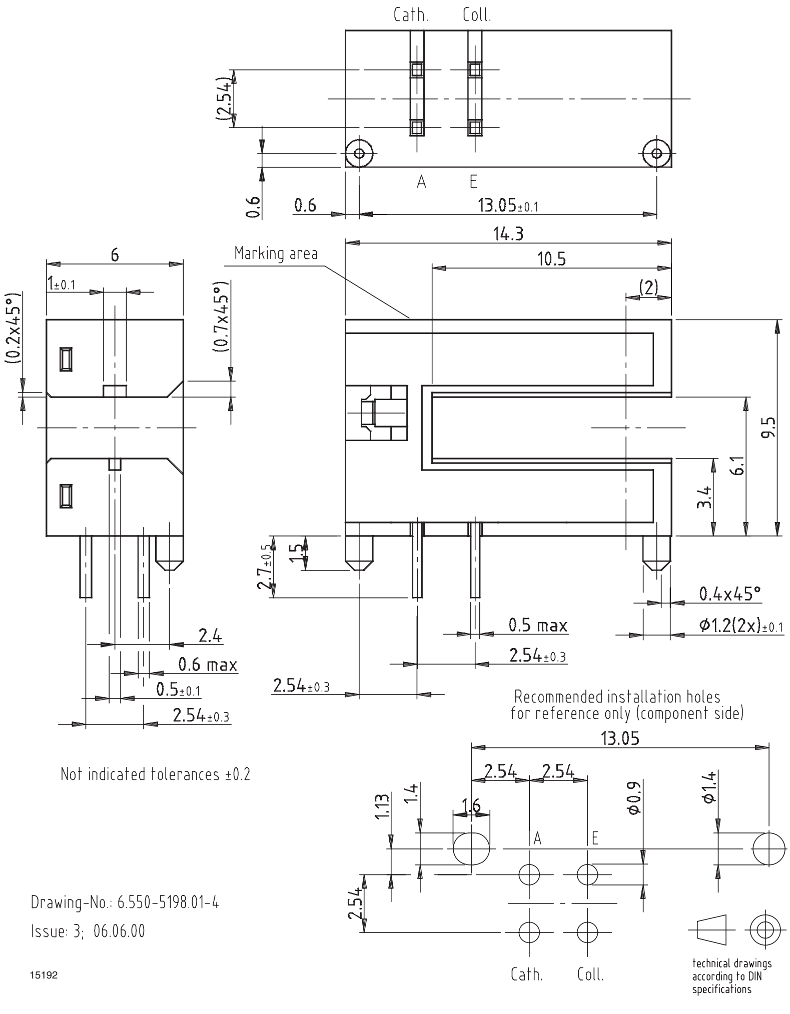


Figure 11. Relative Collector Current vs. Displacement

Package Dimensions in mm



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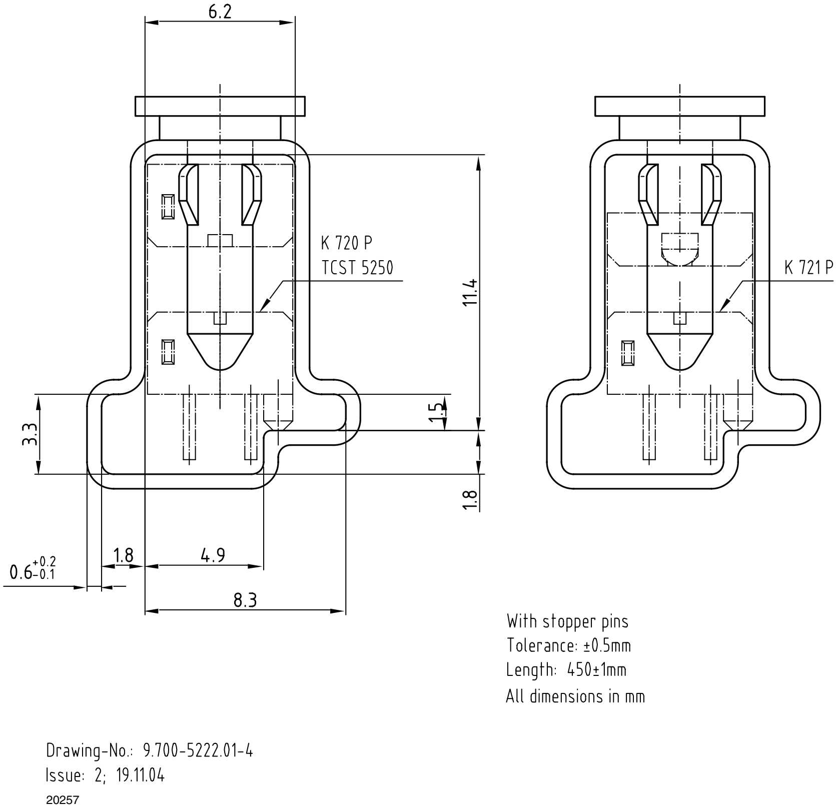
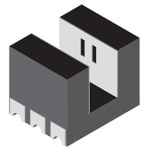
Tube Dimensions

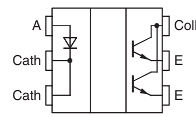


Subminiature Dual-Channel Transmissive Optical Sensor with Phototransistor Outputs

Description

The TCUT1200 is a compact transmissive sensor that includes an infrared emitter and two phototransistor detectors, located face-to-face in a surface-mount package.





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Features

- Package type: Surface-mount
- Detector type: Phototransistor
- Dimensions:
  L 5 mm x W 4 mm x H 4 mm
- Gap: 2 mm
- Aperture: 0.3 mm
- Channel distance (center to center): 0.8 mm
- Typical output current under test: I_C = 0.5 mA
- Emitter wavelength: 950 nm
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC
- Minimum order quantity: 2000 pcs, 2000 pcs/reel

Applications

- Accurate position sensor for encoder
- Detection of motion direction
- Computer mouse and trackballs

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Value	Unit
Power dissipation	$T_{amb} \leq 25$ °C	P	150	mW
Ambient temperature range		T_{amb}	- 40 to +85	°C
Storage temperature range		T_{stg}	- 40 to +100	°C
Soldering temperature	in accordance with fig. 13	T_{sd}	260	°C

Input (Emitter)

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_R	5	V
Forward current		I_F	25	mA
Forward surge current	$t_p \leq 10$ µs	I_{FSM}	100	mA
Power dissipation	$T_{amb} \leq 25$ °C	P_V	75	mW

Output (Detector)

Parameter	Test condition	Symbol	Value	Unit
Collector emitter voltage		V_{CEO}	70	V
Emitter collector voltage		V_{ECO}	7	V
Collector current		I_C	20	mA
Power dissipation	$T_{amb} \leq 25$ °C	P_V	75	mW

Electrical Characteristics

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector current per channel	V_{CE} = 5 V, I_F = 15 mA	I_C	300	500		µA
Collector emitter saturation voltage	I_F = 15 mA, I_C = 0.05 mA	V_{CEsat}			0.4	V

Input (Emitter)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	I_F = 15 mA	V_F		1.2	1.5	V
Reverse current	V_R = 5 V	I_R			10	µA
Junction capacitance	V_R = 0 V, f = 1 MHz	C_j		50		pF

Output (Detector)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector emitter voltage	I_C = 1 mA	V_{CEO}	70			V
Emitter collector voltage	I_E = 100 µA	V_{ECO}	7			V
Collector dark current	V_{CE} = 25 V, I_F = 0, E = 0	I_{CEO}		10	100	nA

Switching Characteristics

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Rise time	I_C = 0.3 mA, V_{CE} = 5 V, R_L = 1000 Ω (see figure 2)	t_r		20.0	150	µs
Fall time	I_C = 0.3 mA, V_{CE} = 5 V, R_L = 1000 Ω (see figure 2)	t_f		30.0	150	µs

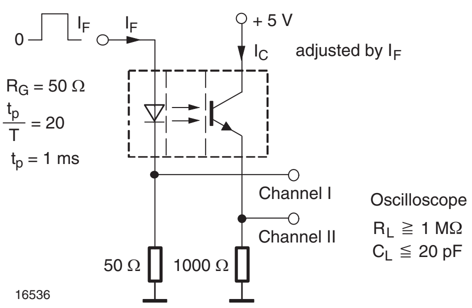


Figure 1. Test Circuit for t_r and t_f

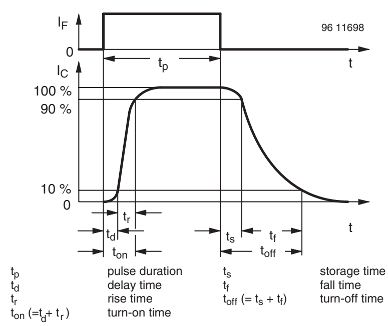


Figure 2. Switching Times

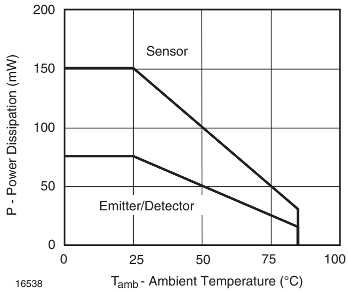


Figure 3. Power Dissipation Limit vs. Ambient Temperature

Typical Characteristics

T_{amb} = 25 °C, unless otherwise specified

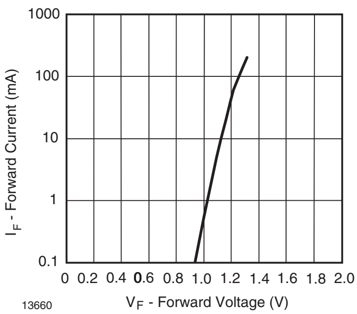


Figure 4. Forward Current vs. Forward Voltage

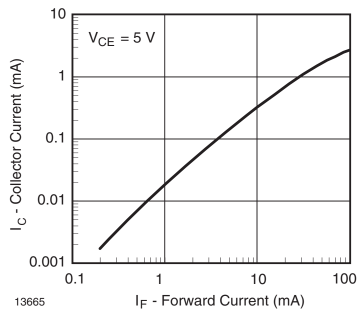


Figure 6. Collector Current vs. Forward Current

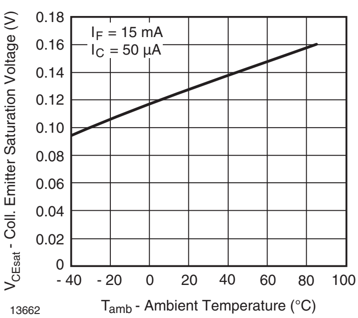


Figure 5. Collector Emitter Saturation Voltage vs. Ambient Temperature

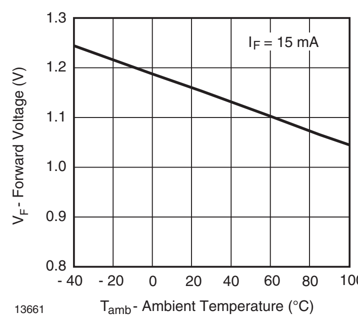


Figure 7. Forward Voltage vs. Ambient Temperature

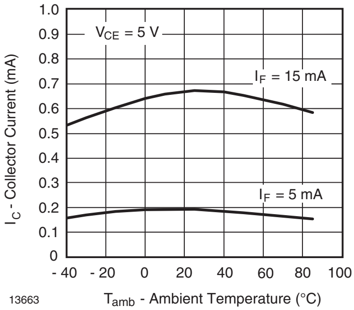


Figure 8. Collector Current vs. Ambient Temperature

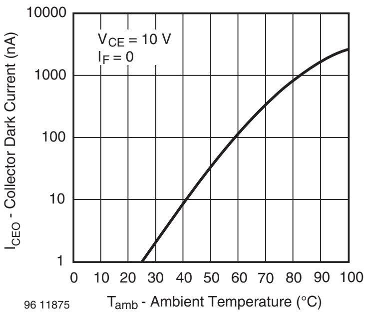


Figure 9. Collector Dark Current vs. Ambient Temperature

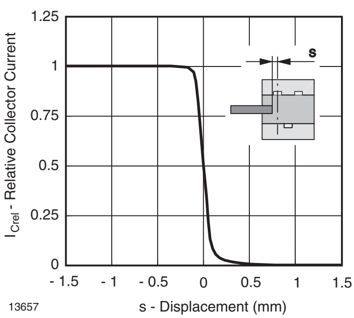


Figure 10. Relative Collector Current vs. Displacement

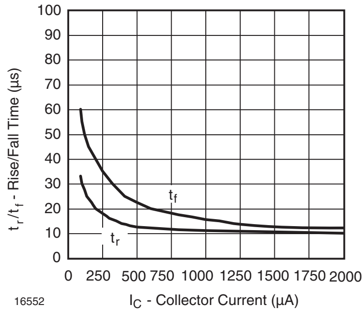


Figure 11. Rise/Fall Time vs. Collector Current

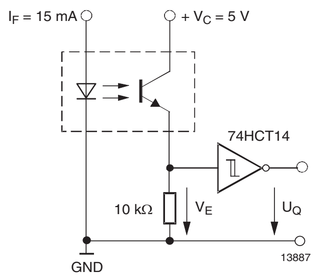


Figure 12. Application example

Reflow Solder Profiles

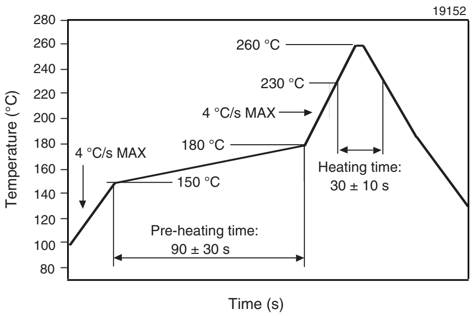


Figure 13. Lead (Pb)-free (Sn) Reflow Solder Profile

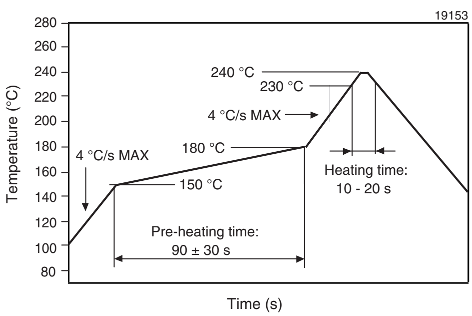


Figure 14. Lead Tin (SnPb) Reflow Solder Profile

Drypack

Devices are packed in moisture barrier bags (MBB) to prevent the products from absorbing moisture during transportation and storage. Each bag contains a desiccant.

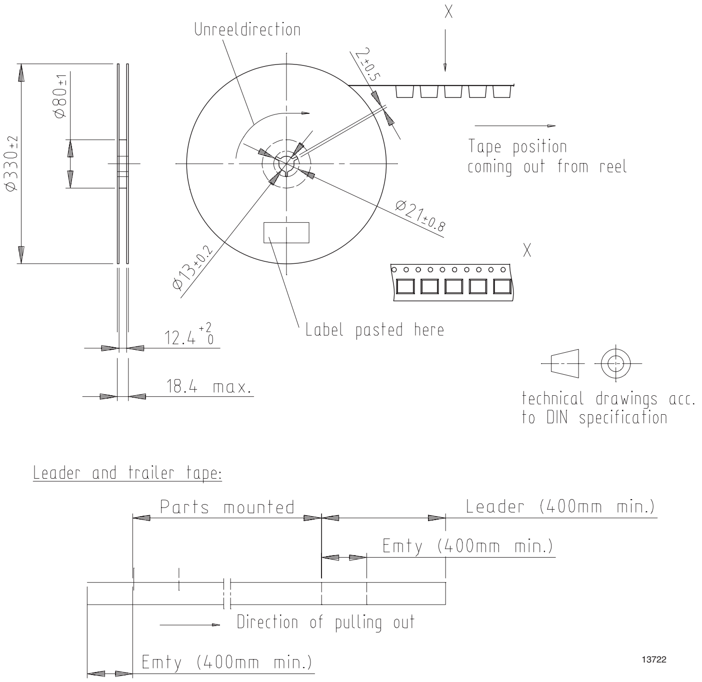
Floor Life

Floor life (time between soldering and removing from MBB) must not exceed the time indicated in J-STD-020. Acc. JEDEC, J-STD-020, TCUT1200 is released to Moisture Sensitivity Level 2, for use of Lead Tin (SnPb) Reflow Solder Profile (figure 14) or Level 3, for use of Lead (Pb)-free (Sn) Reflow Solder Profile (figure 13)
Floor Life: 12 month (level 2) or 168 hours (level 3)
Floor Conditions: T_{amb} < 30 °C, RH < 60 %

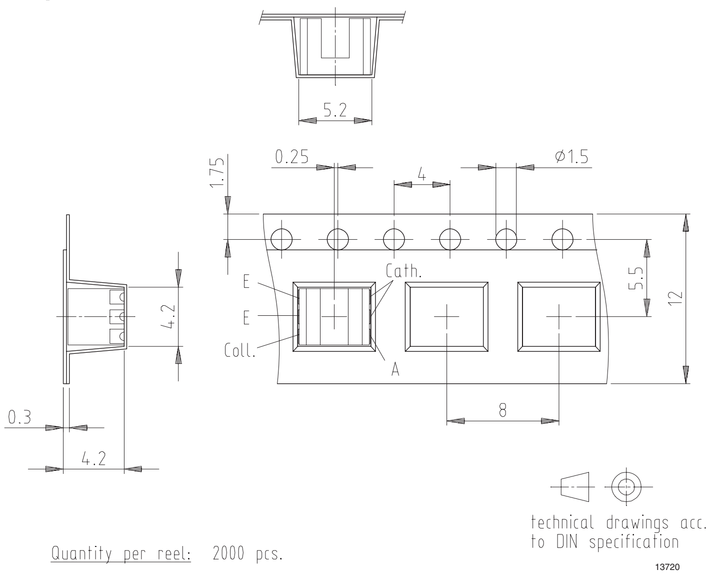
Drying

In case of moisture absorption, devices should be baked before soldering. Conditions see J-STD-020 or Label. Devices taped on reel dry using recommended conditions 192 h at 40 °C (± 5 °C), RH < 5 % or 96 h at 60 °C (± 5 °C), RH < 5 %

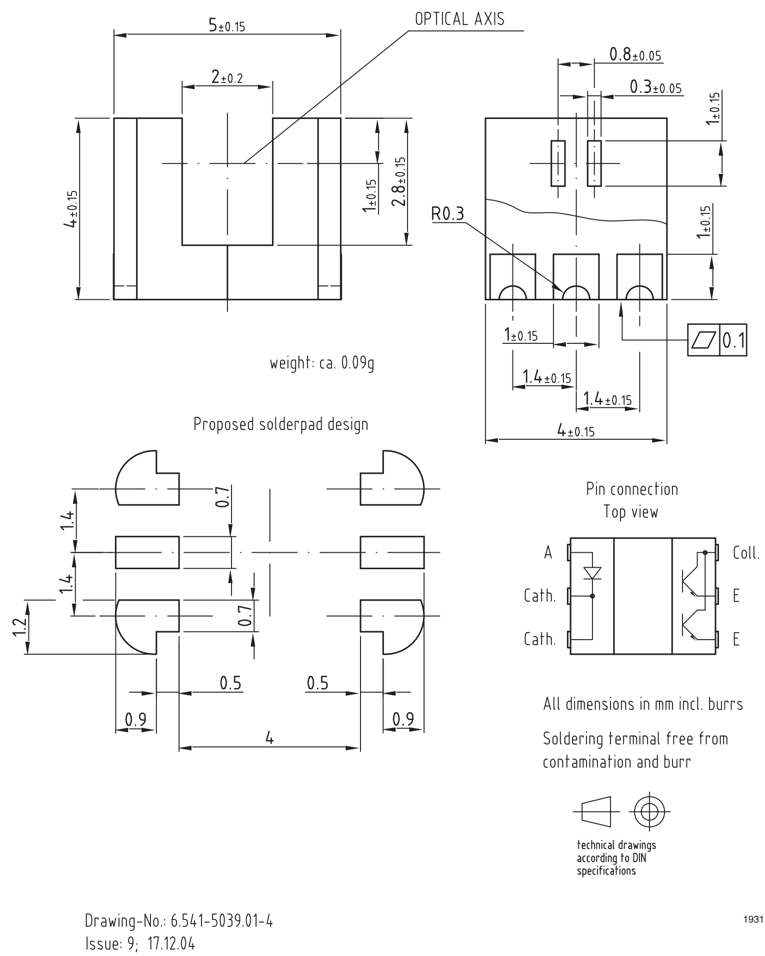
Dimensions of Reel and Tape



Dimensions of Tape



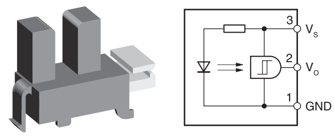
Package Dimensions



Transmissive Optical Sensor with Schmitt-Trigger Logic Output

Description

The TCYS5201 is a transmissive sensor that includes an infrared emitter and a Photo Schmitt-Trigger with digital output interface, located face-to-face on the optical axes. The package blocks visible light and includes mounting clips and a three-pin connector.



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Features

- Package type:
  Connector, 3-pin Molex 5267-NA series order number: 22-03-5035
- Detector type: Photo Schmitt-Trigger
- Dimensions:
  L 19.8 mm x W 9.9 mm x H 18 mm
- Gap: 5 mm
- Aperture: 0.5 mm
- Typical output current under test: I_C = 16 mA
- Output voltage level is LOW, if IR beam is not interrupted
- Output device TTL compliant, open collector
- Daylight blocking filter
- Emitter wavelength: 950 nm
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC
- Minimum order quantity: 400 pcs, 400 pcs/bulk

Applications

- Detection of opaque materials, documents etc.
- Paper position sensor in photocopy machines
- Position sensor for shaft encoders

Handling Precaution

Connect a capacitor with more than 100 nF between V_S and ground in order to stabilize power supply voltage!

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Parameter	Test condition	Symbol	Value	Unit
Supply voltage		V_S	16	V
Output voltage		V_O	30	V
Low level output current		I_{OL}	20	mA
Operation temperature range		T_{amb}	- 25 to + 85	°C
Storage temperature range		T_{stg}	- 40 to + 100	°C

Electrical Characteristics

T_{amb} = 25 °C, unless otherwise specified

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Supply voltage range		V_S	4.5		5.5	V
High level supply current	V_S = 5 V [1)]	I_S		15	30	mA
Low level supply current	V_S = 5 V [2)]	I_S		15	30	mA
High level output voltage	V_S = 5 V, R_L = 1 kΩ [1)]	V_{OH}	4.5			V
Low level output voltage	V_S = 5 V, I_{OL} = 16 mA [2)]	V_{OL}		0.18	0.35	V
Switching frequency	V_S = 5 V, R_L = 47 kΩ	f			3	KHz

[1)] Infrared beam interrupted

[2)] Infrared beam not interrupted

Note: Operating conditions are stabilized after 100 µs of supply voltage turn on.

Switching Characteristics

T_{amb} = 25 °C, unless otherwise specified

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Rise time	V_S = 5 V, R_L = 1 kΩ (see figure 1)	t_r		50.0		ns
Fall time	V_S = 5 V, R_L = 1 kΩ (see figure 1)	t_f		20.0		ns

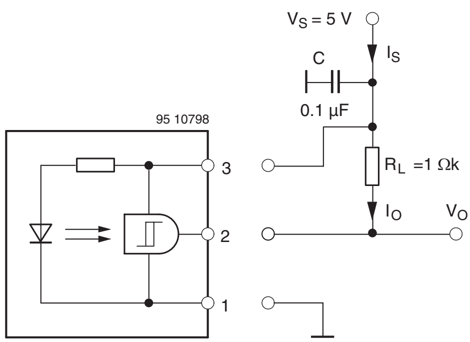


Figure 1. Test circuit and pin connection

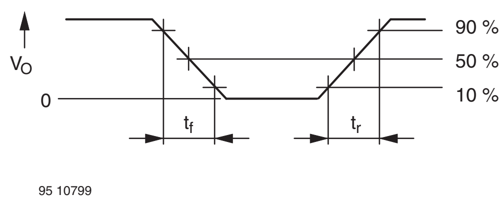


Figure 2. Pulse diagram

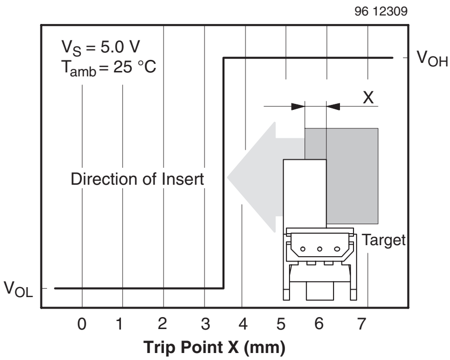


Figure 3. Trip point characteristic

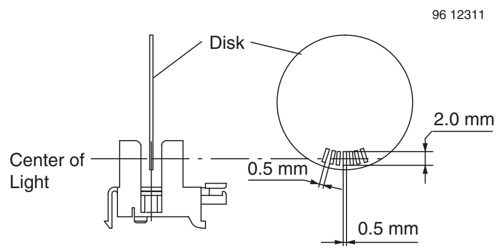


Figure 4. Frequency response

Typical Characteristics

T_{amb} = 25 °C, unless otherwise specified

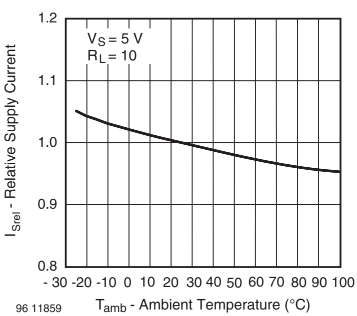


Figure 5. Rel. Supply Current vs. Ambient Temperature

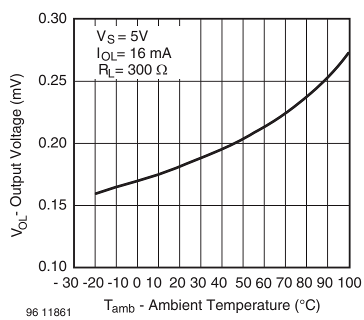


Figure 7. Output Voltage vs. Ambient Temperature

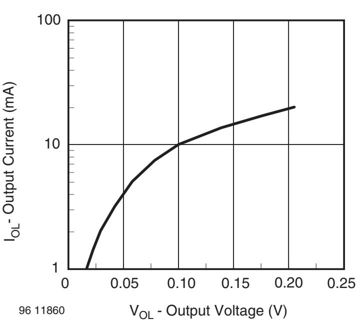
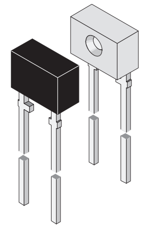


Figure 6. Output Current vs. Output Voltage

Matched Pairs of Emitters and Detectors

Description

The TCZT8020 include matched infrared emitters and phototransistors in leaded packages, used to assemble custom-designed transmissive sensors or reflective sensors. The phototransistor package blocks visible light.



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Features

- Package type: Leaded
- Detector type: Phototransistor
- Dimensions:
  L 4.4 mm x W 2 mm x H 3 mm
- Typical output current under test: I_C = 0.5 mA
- Daylight blocking filter
- Emitter wavelength: 950 nm
- Angle of half intensity: φ = ± 25°
- S420P: single detector component
- V420P: single emitter component
- Lead (Pb)-free soldering released
- Lead (Pb)-free component in accordance with RoHS 2002/95/EC and WEEE 2002/96/EC
- Minimum order quantity: 2500 pairs in bulk

Pb
Pb-free

e4

Applications

- Custom-design sensors for various distances
- Reflective sensors
- Transmissive Sensors

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Value	Unit
Ambient temperature range		T_{amb}	- 55 to + 85	°C
Storage temperature range		T_{stg}	- 55 to + 100	°C
Soldering temperature	Distance to package 2 mm, t ≤ 5 s	T_{sd}	260	°C

Input (Emitter)

Parameter	Test condition	Symbol	Value	Unit
Reverse voltage		V_R	6	V
Forward current		I_F	60	mA
Forward surge current	t ≤ 10 µs	I_{FSM}	1	A
Power dissipation	T_{amb} ≤ 25 °C	P_V	100	mW
Junction temperature		T_j	100	°C

Output (Detector)

Parameter	Test condition	Symbol	Value	Unit
Collector-emitter voltage		V_{CEO}	70	V
Emitter-collector voltage		V_{ECO}	7	V
Collector current		I_C	50	mA
Collector peak current	$t_p/T = 0.5$, $t \leq 10$ ms	I_{CM}	100	mA
Power dissipation	$T_{amb} \leq 25$ °C	P_V	150	mW
Junction temperature		T_j	100	°C

CTR

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
I_C/I_F	$V_{CE} = 5$ V, $I_F = 20$ mA	CTR	0.0125	0.025		

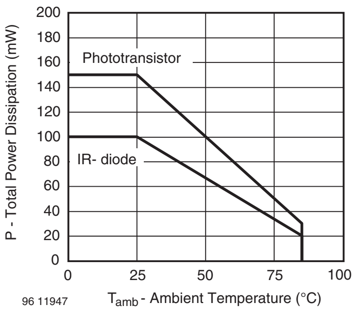


Figure 1. Power Dissipation Limit vs. Ambient Temperature

Electrical Characteristics

$T_{amb} = 25$ °C, unless otherwise specified

Coupler

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector current	$V_{CE} = 5$ V, $I_F = 20$ mA	I_C 1)	0.25	0.5		mA
I_C/I_F	$V_{CE} = 5$ V, $I_F = 20$ mA	CTR	1.25	2.5		
Collector emitter saturation voltage	$I_F = 20$ mA, $I_C = 25$ µA	V_{CEsat}			0.4	V
Cut-off frequency	$I_F = 10$ mA, $V_{CE} = 5$ V, $R_L = 100\ \Omega$	f_C		110		kHz

1) Characteristics are measurement with 4 mm (0.55") distance between emitter and detector, within a common axis of 0.5 mm (0.02") and with parallel alignment within 5°

Input (Emitter)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage	$I_F = 50$ mA	V_F		1.25	1.6	V
Radiant intensity	$I_F = 60$ mA, $t_P = 20$ ms	I_e			7.8	mW/sr
Peak wavelength	$I_F = 100$ mA	λ_P	940			nm
Virtual source diameter	DIN EN ISO 1146/1:2005	Ø		1.1		mm

Output (Detector)

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Collector emitter voltage	I_C = 1 mA	V_{CEO}	70			V
Emitter collector voltage	I_E = 100 µA	V_{ECO}	7			V
Collector dark current	V_{CE} = 25 V, I_F = 0, E = 0	I_{CEO}			100	nA

Switching Characteristics

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Turn-on time	V_S = 5 V, I_C = 1 mA, R_L = 100 Ω (see figure 10)	t_{on}		15.0		µs
Turn-off time	V_S = 5 V, I_C = 1 mA, R_L = 100 Ω (see figure 10)	t_{off}		10.0		µs

Typical Characteristics

T_{amb} = 25 °C, unless otherwise specified

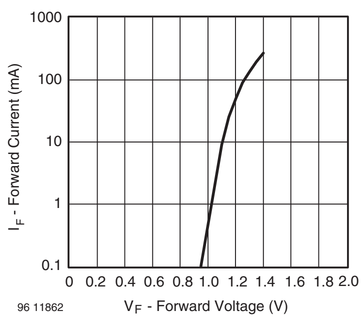


Figure 2. Forward Current vs. Forward Voltage

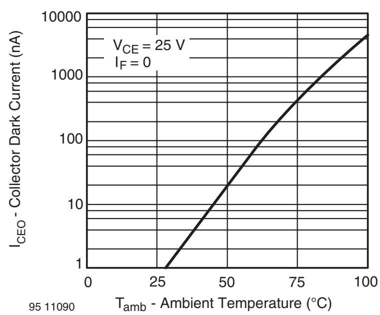


Figure 4. Collector Dark Current vs. Ambient Temperature

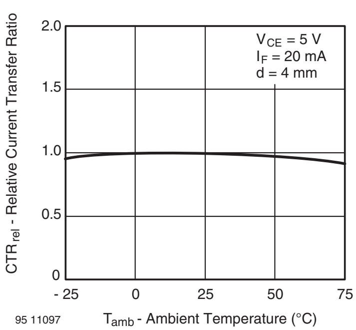


Figure 3. Relative Current Transfer Ratio vs. Ambient Temperature

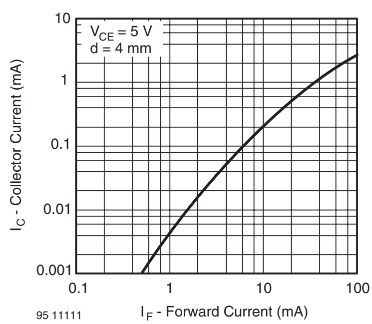


Figure 5. Collector Current vs. Forward Current

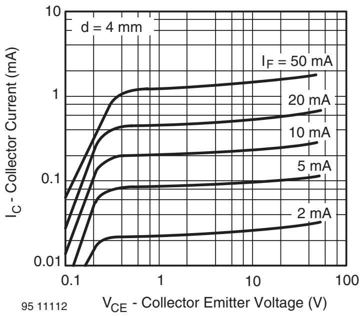


Figure 6. Collector Current vs. Collector Emitter Voltage

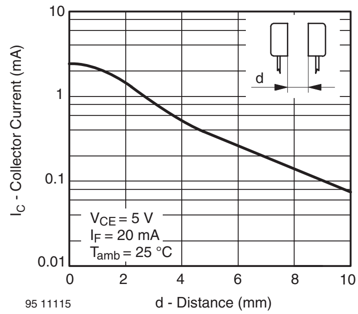


Figure 9. Collector Current vs. Distance

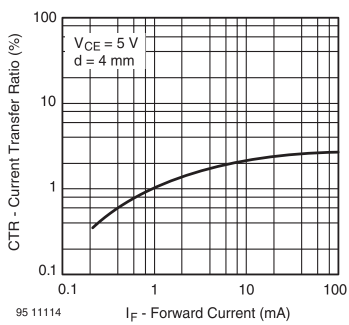


Figure 7. Current Transfer Ratio vs. Forward Current

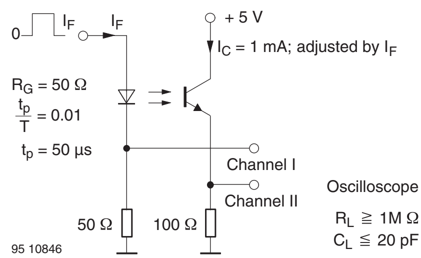


Figure 10. Pulse diagram

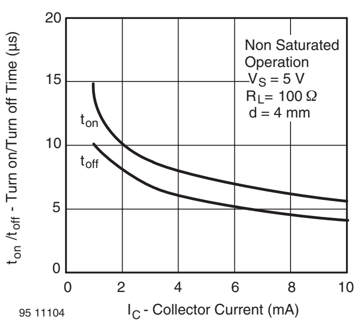


Figure 8. Turn on/off Time vs. Forward Current

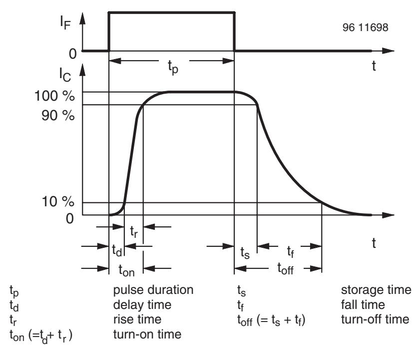
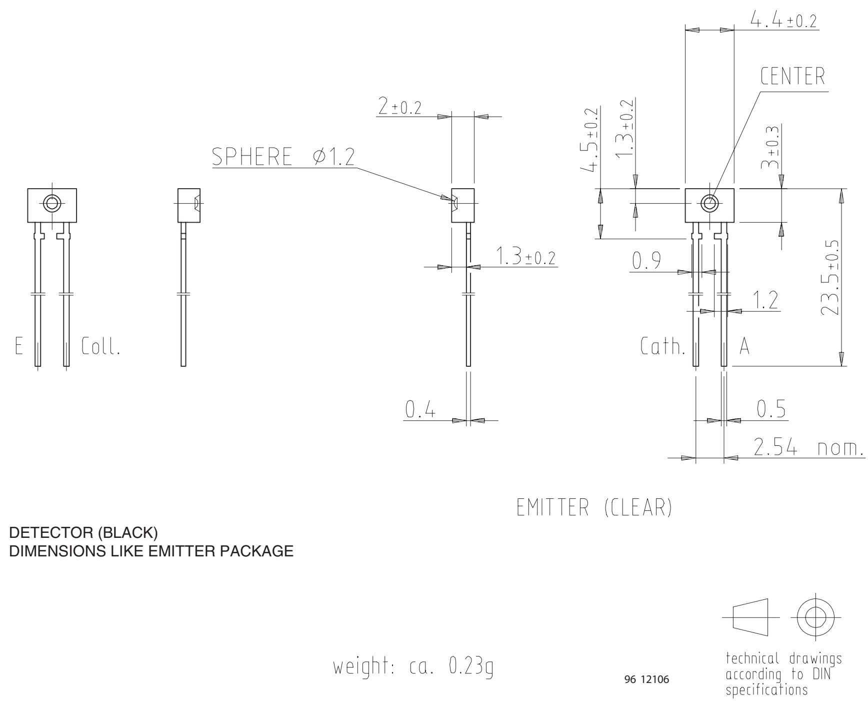


Figure 11. Switching Times

Package Dimensions in mm



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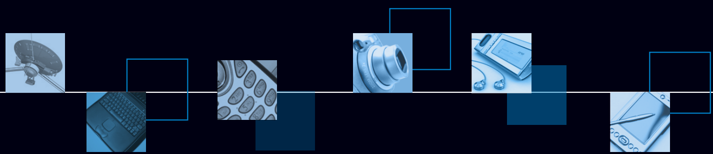

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