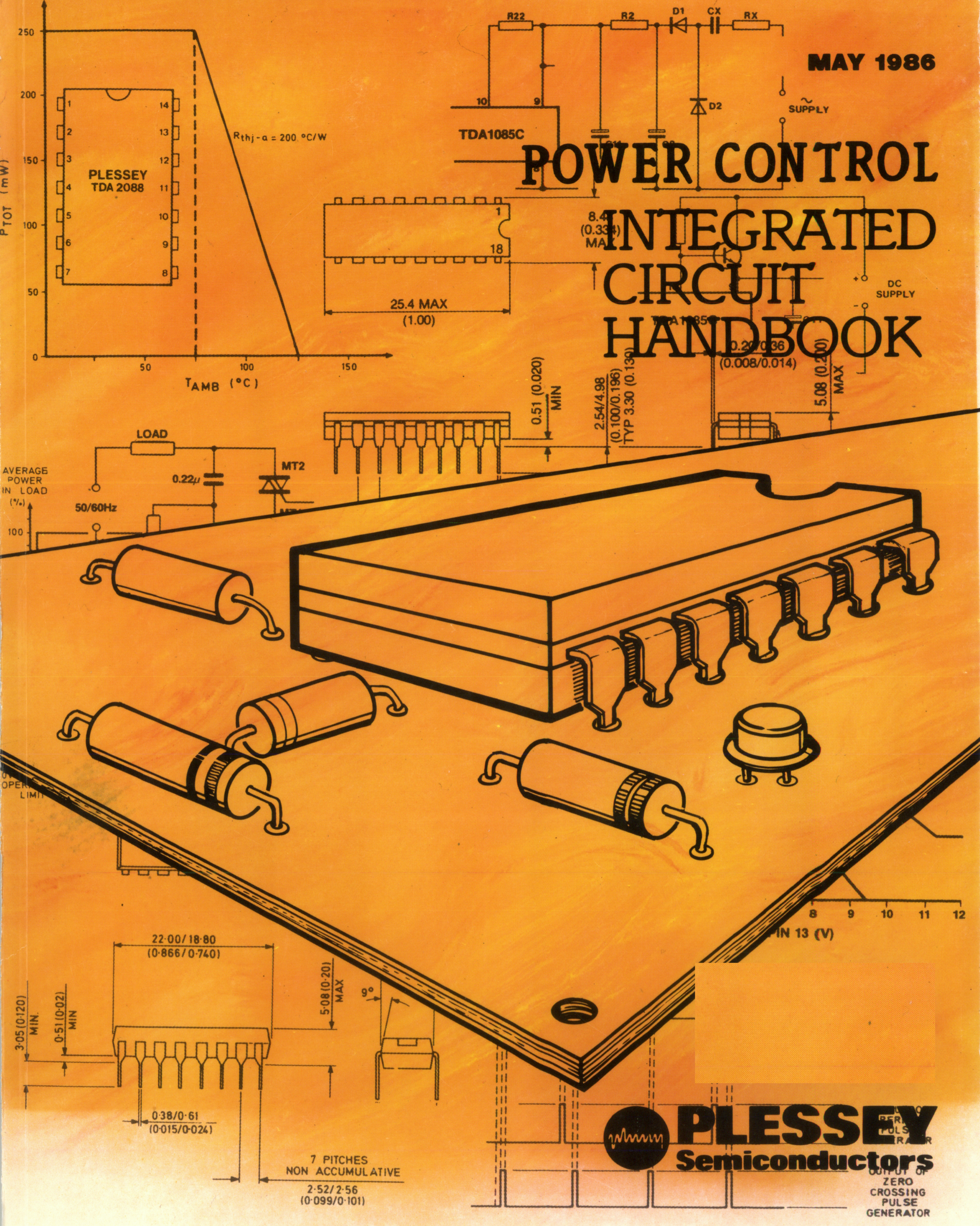
MAY 1986

POWER CONTROL
INTEGRATED CIRCUIT HANDBOOK



PLESSEY
Semiconductors

POWER CONTROL INTEGRATED CIRCUIT HANDBOOK

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Technical Data

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SL440

POWER CONTROL CIRCUIT

The SL440 is a versatile integrated circuit designed to provide variable-phase control of triacs and other power switching devices in a variety of domestic and industrial applications. The basic elements of the SL440 are shown in Fig.2.

An external timing capacitor, C_T, connected to pin 14 is discharged during positive and negative half cycles of the driving waveform (typically 50Hz), at a constant rate which is proportional to the output of the servo amplifier (pin 13). When the charge reaches an internally-defined level, the conduction control cicuit generates a 50μs (typ.) firing pulse (pin 1) to trigger the triac. The crossover detector resets the timing cycle when the driving waveform passes through zero, at which point C_T is recharged rapidly. The servo amplifier thus controls the conduction time of the triac, and hence the power delivered to the load.

If the Inhibit input (pin 4) is taken below +5V (e.g. to pin 11) the conduction control circuit action is over-ridden and the firing pulses are inhibited. This facility can be used in conjunction with the current limit detector, by driving the AC input terminals (pins 5 and 10) from a current transformer in series with the load. If a load resistor is connected from pin 4 to the stabilised supply (pin 3), a DC voltage, inversely proportional to the AC load current, appears on pin 4. This is applied to the variable delay pulse generator as soon as the internally defined threshold voltage (approximately 5V) exceeds it, and so limits the load current.

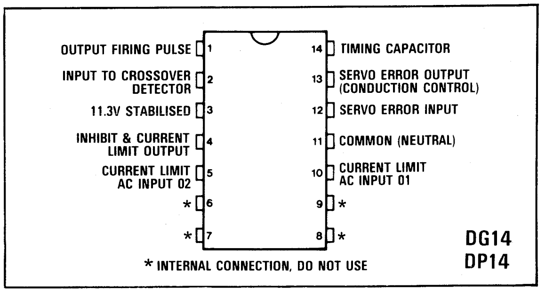


Fig.1 Pin connections (top view)

FEATURES

- Conduction Control
- Crossover Detector
- Servo Amplifier
- Internal Stabilised Supply
  (Available for External Circuitry)
- Total Power Shut-Down Facility
- AC Load Current Limitation

APPLICATIONS

- Lamp Dimmers
- Automatic Lamp Faders
- Motor Speed Control

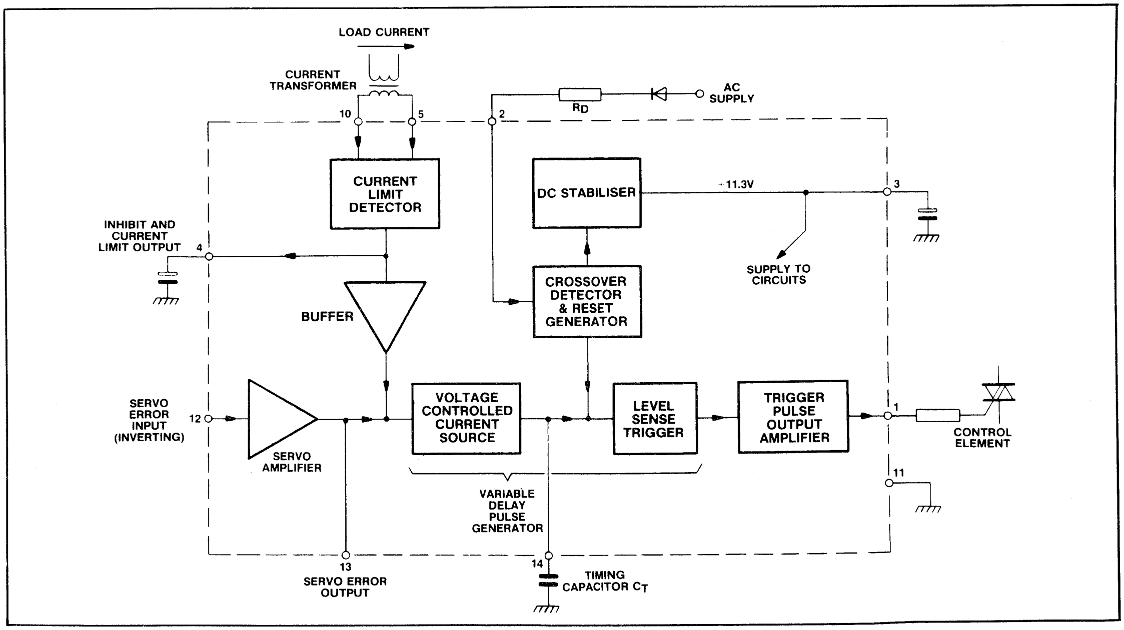


Fig.2 SL440 functional block diagram

ELECTRICAL CHARACTERISTICS

Test conditions (unless otherwise stated):

$T_{amb} = +25°C$

Characteristics	Value			Units	Conditions
	Min.	Typ.	Max.		
Firing pulse width		50		μs	
Max. pulse current	60	120		mA	
Current to pin 3	15		30	mA	Rectified AC
Voltage at pin 3 (internally stabilised)		11.3		+V	
Inhibit operating voltage (pin 4)	0		5	+V	
Static gain of servo amplifier		75		-	Typical application, gain $= \frac{R_L}{2k}$
Current limit input threshold		±0.7		V	

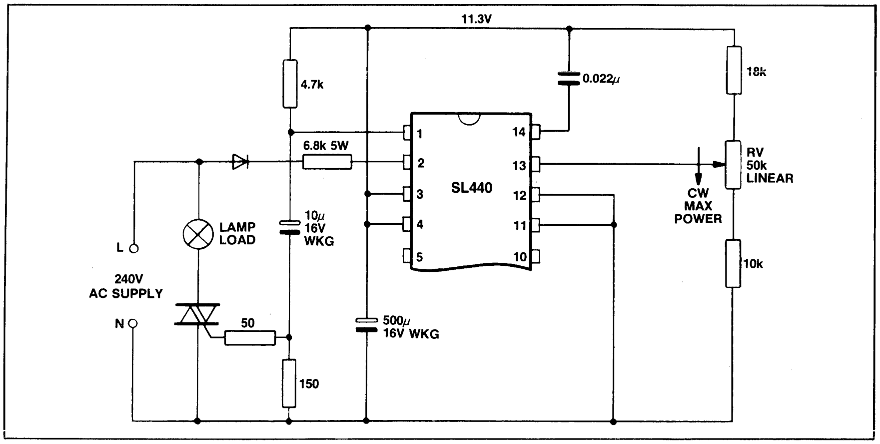


Fig.3 Lamp dimmer using minimum components

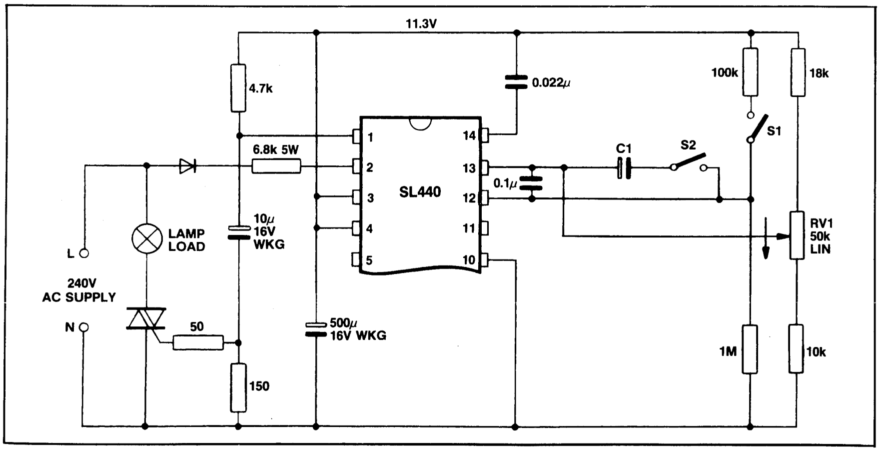


Fig.4 Automatic lamp fading circuit

APPLICATION NOTES

A simple, manually-controlled, lamp dimmer circuit is shown in Fig.3. In this application, the servo amplifier is not used; proportional control of lamp brightness is effected by the voltage applied via RV1 to the servo amplifier output (pin 13) which is internally connected to the conduction control circuit.

A more sophisticated use of the SL440 is shown in Fig.4 an automatic lamp fading circuit which has applications in a variety of domestic environments. The circuit is used as follows: with S1 and S2 both open, the level of brightness is directly controlled by the setting of RV1. When S1 is closed, the positive voltage applied to pin 12 causes firing pulses to be produced at a conduction angle approaching 180° (Fig.5) and the lamp brightness is maximum. When S2 is closed and

S1 is opened, the servo amplifier acts as an integrator due to the Miller action of C1 and the lamp brightness fades progressively to the level previously set by RV1. The fade rate is determined by the choice of C1: for example, a 250 microfarad capacitor will result in a subjectively imperceptible fade rate of 20-30 minutes.

Fig.6 shows the SL440 used in a motor speed control circuit. The DC motor/tacho-generator is used in a velocity servo loop in which motor velocity is linearly proportional to the setting of RV1. RV2 controls the maximum motor current in the range 1 to 10A.

OPERATING NOTES

In applications where RF radiation is a problem, it is recommended that the filter circuit shown in Fig.7 be used.

Where the SL440 is used for domestic light dimming, or in other applications where the power dissipated in the dropping resistor RD is considered excessive, the series rectifier and dropping resistor can be replaced by the circuit shown in Fig.8. The series capacitor, together with the low impedance at pin 3, provides a degree of RF filtering at the AC supply terminals.

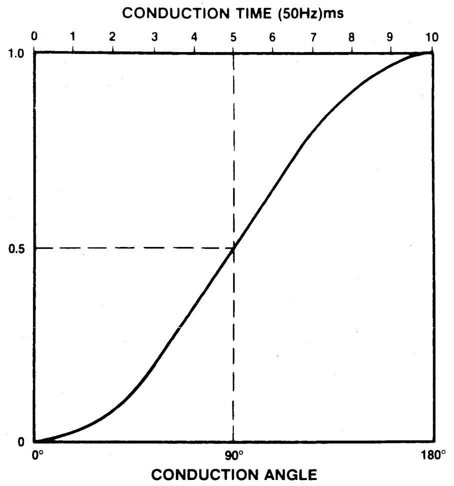


Fig.5 Triac conduction angle v. sinewave load power

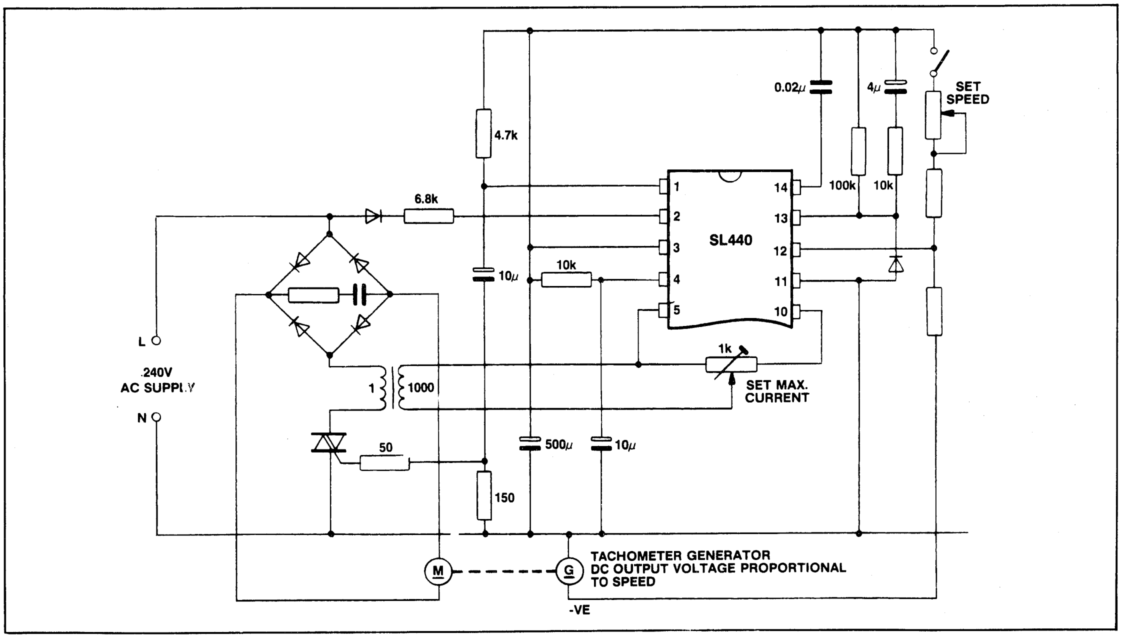


Fig.6 Servomotor control with motor current limiting

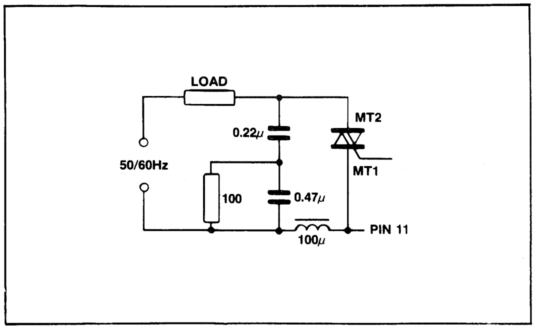
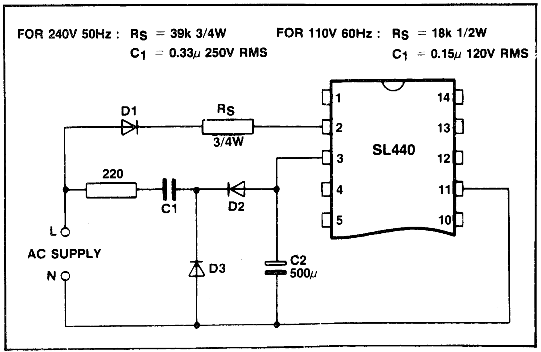


Fig.7 RF filter for loads less than 100W or inductive. For load of 100W and above, use 100μH and 0.1μF only.


FOR 240V 50Hz : R_S = 39k 3/4W
C_1 = 0.33μ 250V RMS

FOR 110V 60Hz : R_S = 18k 1/2W
C_1 = 0.15μ 120V RMS

Fig.8 Low loss power supply

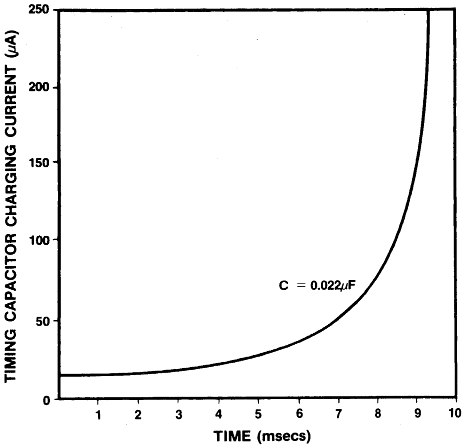


Fig.9 Triac conduction time v. capacitor charging current

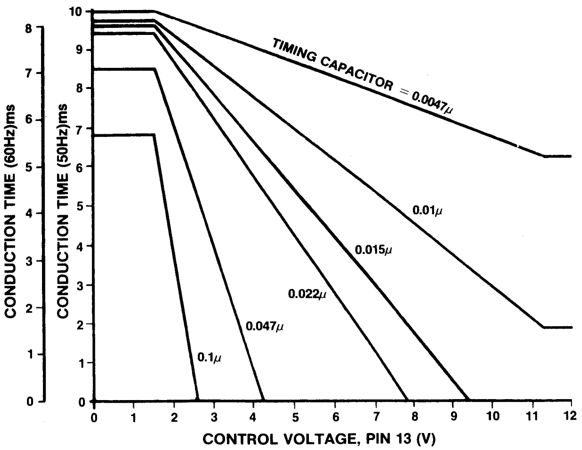


Fig.10 Triac conduction time v. servo amplifier output (demonstrating linear relationship)

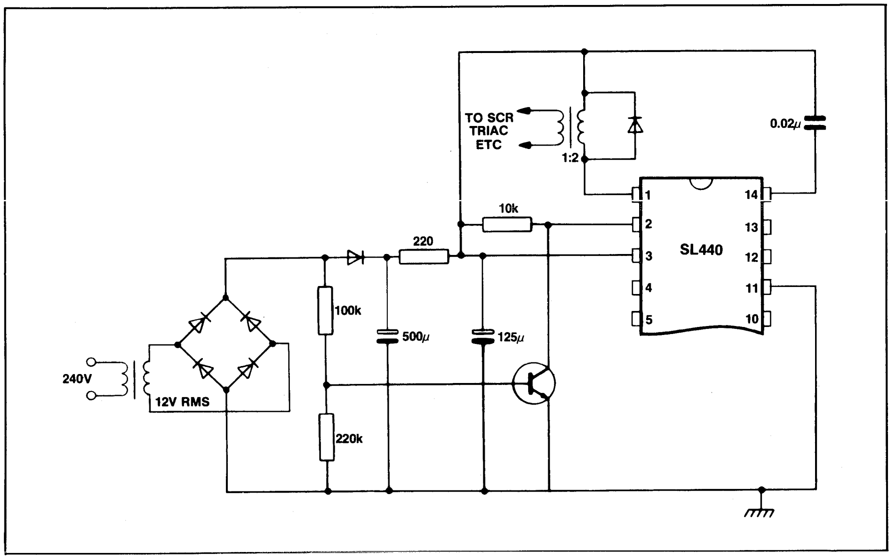


Fig.11 Fully isolated supply operation of SL440, featuring full-wave crossover detection for symmetrical timing. Additional SL440s can be powered via separate 220Ω feed resistors, synchronising being achieved by connecting pin 2 of each SL440 to the collector of the common sync. transistor TR1.

ABSOLUTE MAXIMUM RATINGS

Storage temperature	-55°C to +125°C
Operating temperature	-10°C to +65°C
Package dissipation	600mW
Supply current to pin 2	200mA DC

NOTE

Where the SL440 is to be used in a device socket, care should be taken to ensure that the reservoir capacitor on pin 3 is discharged before inserting the device. Failure to observe this precaution may result in damage to the internal shunt stabiliser.

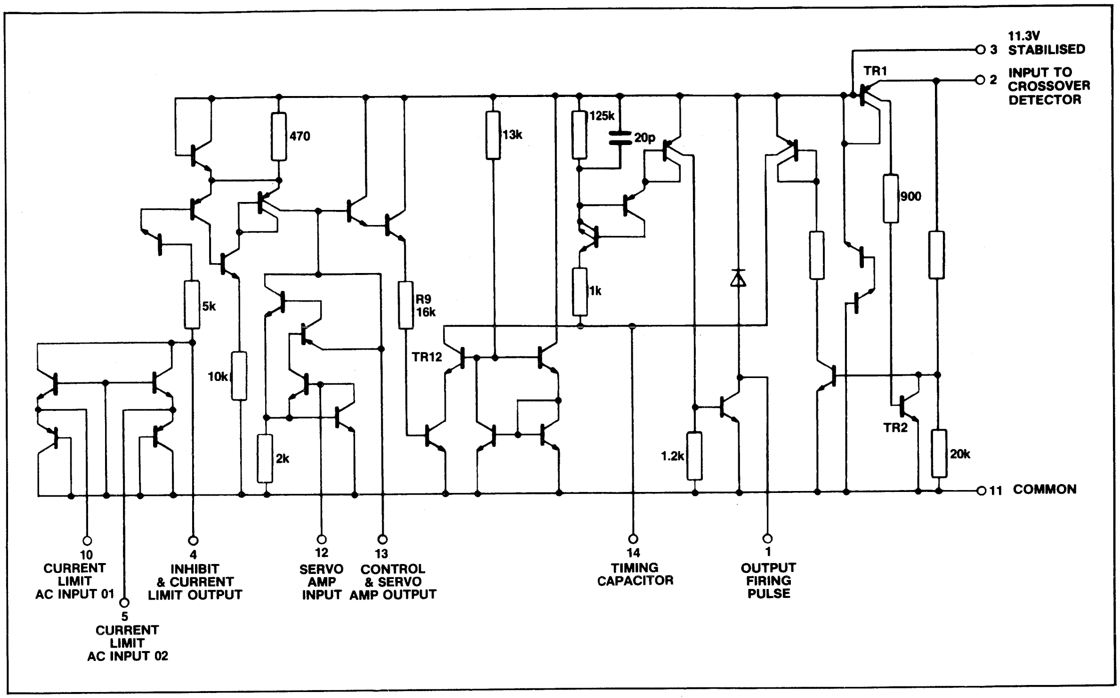
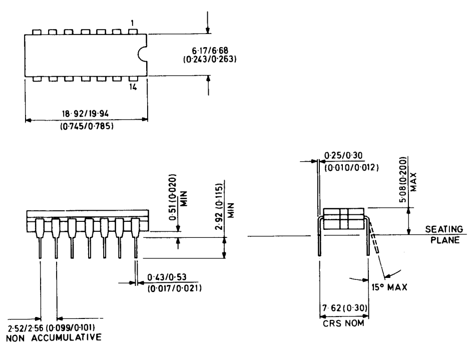


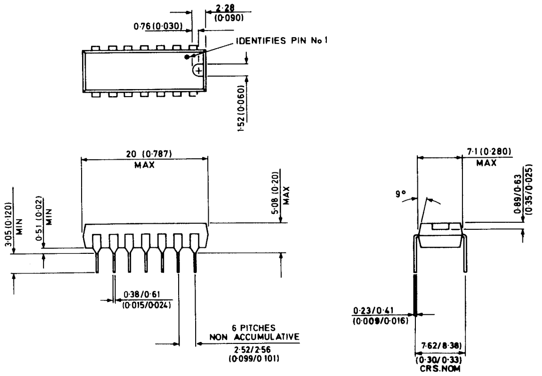
Fig.12 Circuit diagram of SL440

PACKAGE DETAILS

Dimensions are shown thus: mm (in)



14 LEAD CERAMIC DIL **DG14**



14 LEAD PLASTIC DIL **DP14**

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SL441C

ZERO VOLTAGE SWITCH

The SL441C is a symmetrical burst control integrated circuit in an 8 pin DIL package. When used with a triac, AC power may be regulated by varying the number of mains cycles applied to the load in a fixed timing period. The device is especially suited to room temperature control applications including panel heaters, fan heaters etc. Zero Voltage Switching has the advantage of minimising radio frequency interference.

SPECIAL FEATURES

1. Balanced zero voltage point crossing detector, spike filter and pulse generator for reliable triggering of the triac.
2. A period pulse generator and bistable which are arranged to provide symmetrical burst control and eliminate ½ wave firing. (EN50.006, BS5406, 1976)
3. A ramp generator whose output is used to modify an internal reference voltage which is then compared with the voltage appearing on the thermistor to form a proportional control system. The period of the ramp generator is defined externally and may be chosen to limit 'lamp flicker' in accordance with EN50.006/ BS5406, 1976.
4. The comparison amplifier has inbuilt hysteresis to eliminate switching jitter and a spike filter/sampling circuit to provide high immunity to both spikes and coherent 50Hz/60Hz.
5. Thermistor malfunction may be sensed and power automatically removed.
6. A supply voltage sensing circuit which inhibits firing pulses when the supply is inadequate to guarantee proper circuit operation. This eliminates stressing of the triac at switch-on.

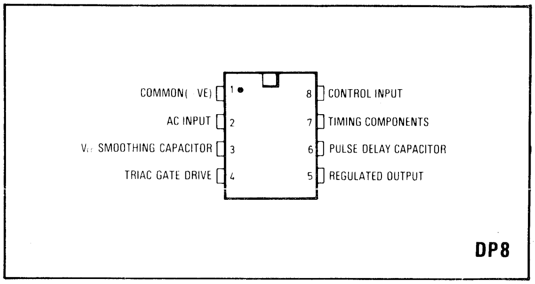


Fig.1 Pin connections (top view)

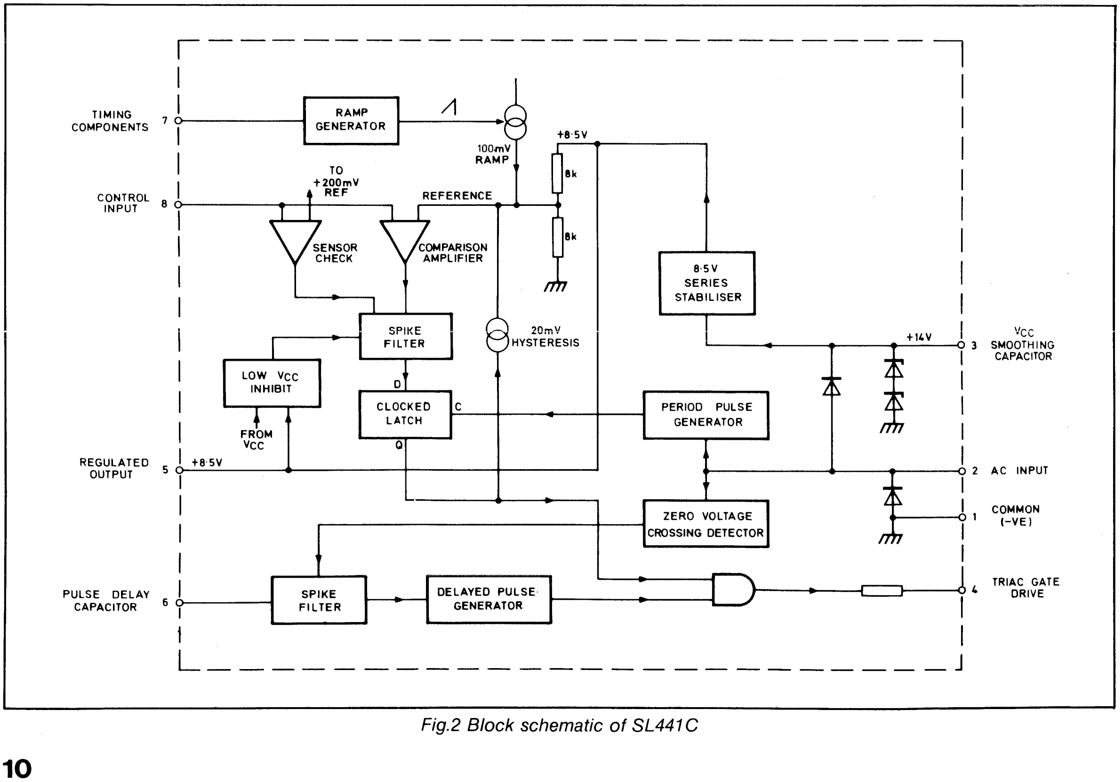


Fig.2 Block schematic of SL441C

ELECTRICAL CHARACTERISTICS

Test conditions (unless otherwise stated):

$T_{AMB} = 25°C$

All voltages measured with respect to common (pin 1)

Characteristics	Value Min.	Value Typ.	Value Max.	Units
Shunt regulating voltage pin 3 @ 16mA		14.7		V
Shunt regulating voltage pin 3 @ 16mA @ 75°C			16	V
Supply voltage trip level pin 3		12.2		V
Supply current (less I_4AV, I_5) (see Note 1)			7.5	mA
Regulated voltage pin 5	8.0	8.5	9.0	V
Regulated voltage temperature coefficient pin 5	−1		+1	mV/°C
Triac gate drive pin 4 (See Note 2)				
Open circuit ON voltage		8.5		V
Open circuit OFF voltage			0.1	V
Output current into 2V drain	100	130		mA
Output current into 4V drain	65	80		mA
Output current into short circuit			200	mA
Internal drain resistance		800		Ω
Control input pin 8				
Bias current			1	µA
Hysteresis		20		mV
Sensor malfunction circuit operates at	150	200	250	mV
Input working voltage range	0		12	V
Internal reference voltage (Ramp start) (See Note 3)	4.0	4.25	4.5	V
Internal reference voltage (Ramp finish) (See Note 3)		4.35		V
Peak-to-peak amplitude of ramp	70	100	130	mV
Pin 6 output impedance (R6) (See Note 2)	21.5	27	32.5	kΩ
Maximum ripple voltage pin 3			1	V_{P-P}

NOTES

1. The supply current is 0.45 × (RMS current fed into pin 2). I_5 is the current drained from pin 5 externally. I_{4AV} is the average triac gate current supplied each mains cycle.
2. Triac firing pulse. t_p Pulse width = 0.69 $R6C_D$µs typical
   t_f Pulse finish = 1.09 $R6C_D$ µs minimum after zero voltage point R6 in kΩ, C_D in nF See Application circuit
   t_p Nominal (C_D = 2.7nF) = 50µs
   t_f Minimum (C_D = 2.7nF) = 63µs
3. Ramp period 0.85 ±0.15 × R_TC_T sec. See Application circuit. The actual value of R_t must lie between 500kΩ and 3MΩ.

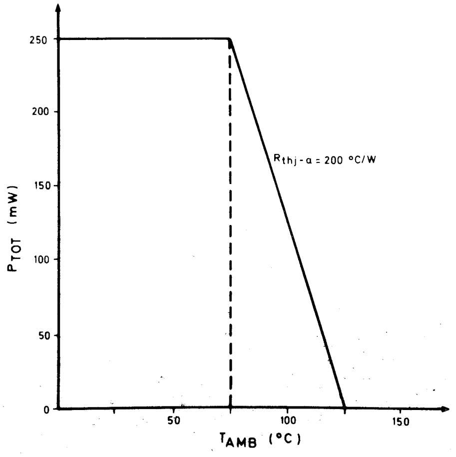


Fig. 3 Power dissipation

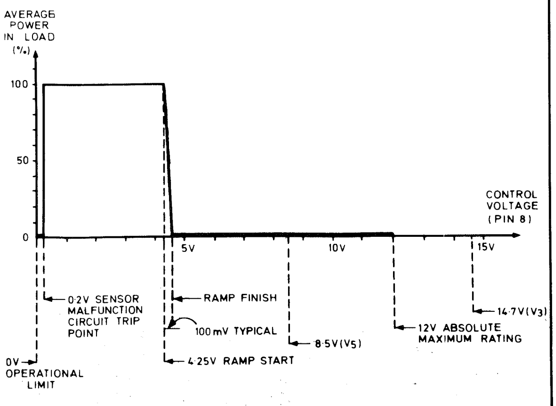


Fig. 4 Control characteristic of pin 8

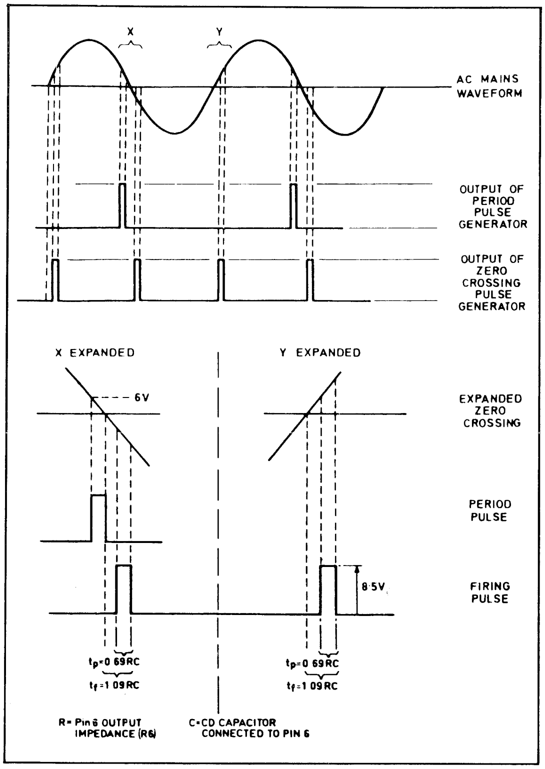


Fig. 5 Pulse timing

ABSOLUTE MAXIMUM RATINGS

Voltages

Voltage on pin 8 V_{8-1} Max. 12V
Voltage on pin 4 V_{4-1} Max. 10V

Currents

Supply current (pin 2) Peak value ± I_{2M} 50mA.
Non-repetitive peak current (tp ⩽250µs) ± I_{2SM} 200mA.
Output current (pin 5) Max. 5mA Short circuit protected.
Output current (pin 4) average value $I_{4(AV)}$ Max 5mA Short circuit protected.

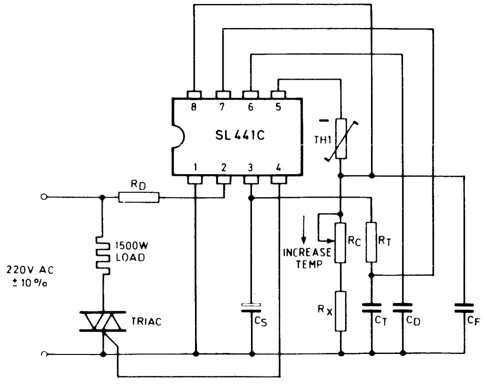
Temperature

Operating ambient temperature T_{AMB} —10°C to +75°C
Storage temperature T_{STG} —30°C to +125°C

APPLICATIONS

Electronic thermostat for room heater

The circuit in Fig. 6 has a sensitivity of nominally 100mV/°C. The width of the proportional control band is nominally 1.0°C and offers a good compromise between temperature stability and regulation performance. For potentiometer control characteristics see Figs. 7 and 8.



SUGGESTED VALUES

R_D	8.2kΩ 5% 6W (less in air stream)	
R_C	22kΩ linear control potentiometer	
R_t	2.7MΩ	Ramp period = 11 secs.*
C_t	4.7µF 10V TANT	
C_f	47nF (filter if required)	
C_S	150µF 16V	
C_D	2.2nF ±10%	
Triac	TAG 250-400	

TH1 NTC thermistor. R_{25} = 10kΩ
B = 4200. e.g. ITT KQ103
R_x 6.2k ±5% fixed resistor or 10kΩ preset.
See control characteristics Figs. 7 and 8

*If on-off control is required, omit R_T and C_T and link pin 7 to pin 1.

*Fig.6 Application circuit for proportional control system.**

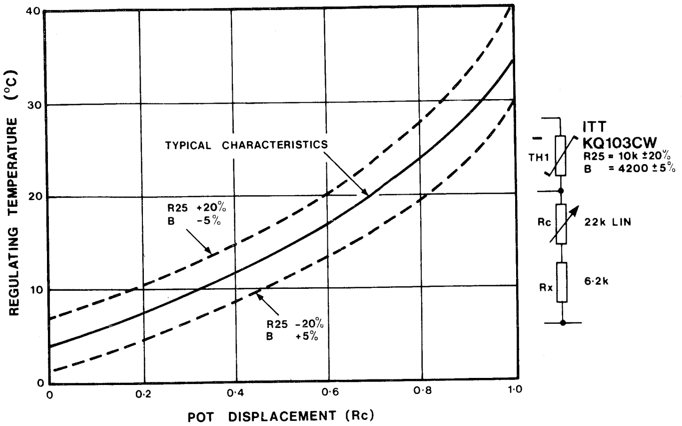


Fig.7 Control characteristics of electronic room thermostat (mechanical calibration)

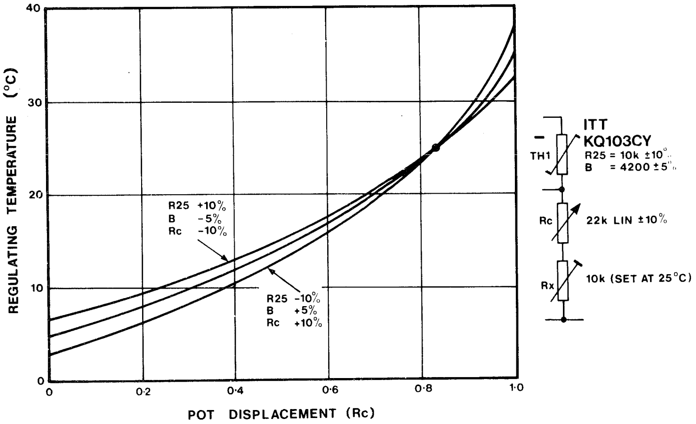
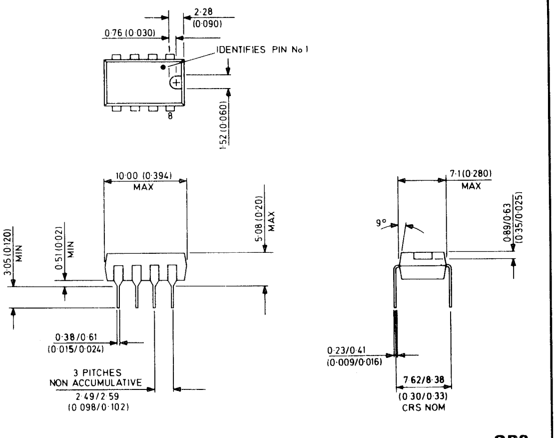


Fig.8 Control characteristics of electronic room thermostat (electrical calibration)

PACKAGE DETAILS

Dimensions are shown thus: mm (in)



8 LEAD PLASTIC DIL **DP8**

PLESSEY
Semiconductors

SL443A

ZERO VOLTAGE SWITCH

The SL443A is a symmetrical burst control integrated circuit in an 8-pin DIL plastic package and is mainly intended for manual heat control applications, for example cooker hot plates and powerful hair dryers.

SPECIAL FEATURES

1. Well defined load power/potentiometer displacement characteristics
2. High immunity against spurious triac firing under noisy mains environment (automatic spike filtration)
3. Enables compliance with Cenelec EN50,006/ BS5406-1976
    (A) Switching rate controlled
    (B) symmetrical burst control
4. Very low external component count
5. Triac firing pulses inhibited whilst the IC's power supply is being established.

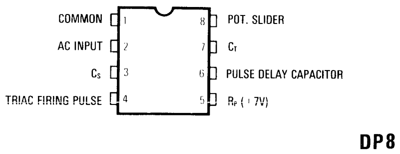


Fig.1 Pin connections - top view

APPLICATIONS

- ■ Cooker hotplates
- ■ Powerful hairdryers

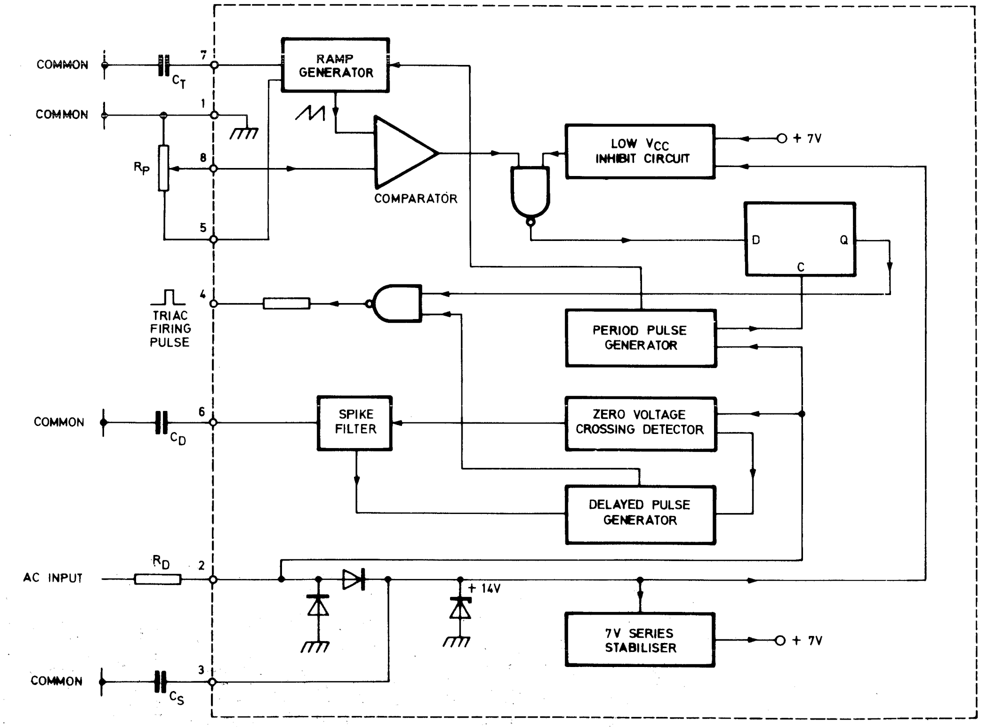


Fig.2 SL443A block diagram

CIRCUIT DESCRIPTION

The externally current limited AC supply is applied to the device, and rectification followed by shunt regulation provides a 14V DC supply. This is externally smoothed before application to the 7.0V series stabiliser which feeds the resistance bridge. The stabiliser must be within regulation, or operation of the 'Low Vcc Inhibit' circuit will result. This circuit overrides all other circuitry and prevents unsuitable firing pulses from being supplied to the triac at 'switch-on'. The current limited AC supply also drives the Period Pulse Generator (PPG) and zero voltage crossing circuits.

The PPG produces a single short duration pulse for each completed mains cycle and serves two purposes. Firstly it is used to clock logic information such that the circuit behaves in a symmetrical manner and only complete mains cycles are applied to the load. Secondly the pulse is used to switch timing components in the ramp generator and this enables long time constants to be achieved without having to resort to the use of electrolytic capacitors.

The zero voltage crossing detector controls a pulse generator that has a delayed output. The delay is necessary since, with loads that are slightly inductive or low power resistive, the triac load current may not reach its required holding level at zero voltage point.

Both delay and pulse duration are defined by an external capacitor and this further serves the purpose of filtering out spikes which occur in the zero crossing region. Automatic rejection takes place of spikes having a duration of up to 50 per cent of the normal width of the triac firing pulse.

The comparator amplifier has differential inputs and these are used to compare the potential appearing on the slider of the control potentiometer with that of the ramp waveform. The output of this amplifier controls the logic circuitry and the potentiometer setting defines the fraction of the ramp period for which the triac is in conduction so controlling the power in the load.

ELECTRICAL CHARACTERISTICS

Test Conditions (unless otherwise stated)

$T_{AMB} = 25°C$,
All voltages measured with respect to common (pin 1)

Characteristic	Value			Units	Conditions
	Min.	Typ.	Max.		
Shunt regulating voltage pin 3		14.7		V	$I_3 = 16mA$
Shunt regulating voltage pin 3			16	V	$I_3 = 16mA$, $T_{amb} = +75°C$
Supply voltage trip level pin 3		12.2		V	
•Supply current (less I_4 AV, $2 \times I_5$) See Note 1			7.2	mA	
Potentiometer supply pin 5, V_5	6.8	7.0	7.6	V	
Potentiometer resistance range	18		140	kΩ	
Triac gate drive pin 4					
Open circuit ON voltage		8.5		V	
Open circuit OFF voltage			0.1	V	
Output current into 2V drain	80	100		mA	
Output current into 4V drain	50	70		mA	
Output current into short circuit			200	mA	
Internal drain resistance		800		Ω	
Control input pin 8					
Bias current			1	μA	
Internal reference – ramp start	0.3	0.5	0.7		
– ramp finish	$V_5 - 0.5$	$V_5 - 0.3$	$V_5 - 0.1$		
★ Period of ramp generator – T	27	30	33	s	(R_P = 100K, C_t = 0.68μ) (RMS mains voltage=220v)
Pin 6 output impedance R6	21.5	27	32.5	kΩ	

● The supply current is 0.45 x (RMS current fed into Pin 2)

★ Period of ramp $= T = 2 \times C_T \times R_P \times$ (RMS mains voltage) seconds

ABSOLUTE MAXIMUM RATINGS

Voltages			
Voltage on pin 8,	V_{8-1}	Max	10v
Voltage on pin 4,	V_{4-1}	Max	10v
Currents			
Supply current, pin 2 peak value	$\pm I_{2M}$	Max	50mA
Non-repetitive peak current ($t_P \geqslant 250\mu S$)	$\pm I_{2SM}$	Max	200mA
Output current, pin 5	I_5	Short circuit protected	
Output current, pin 4, average value	I_4 (AV)	Max	10mA
		Short circuit protected	
Temperatures			
Operating ambient temperature		T_{AMB}	—10 to 75°C
Storage temperature		T_{STG}	—55 to +125°C
Power Dissipation		See Fig. 3	

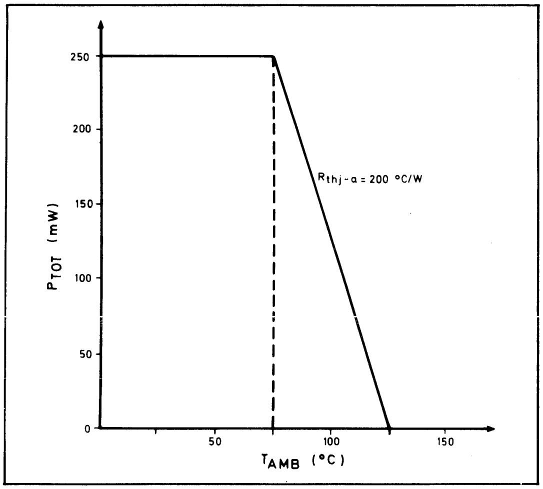


Fig. 3 Power dissipation

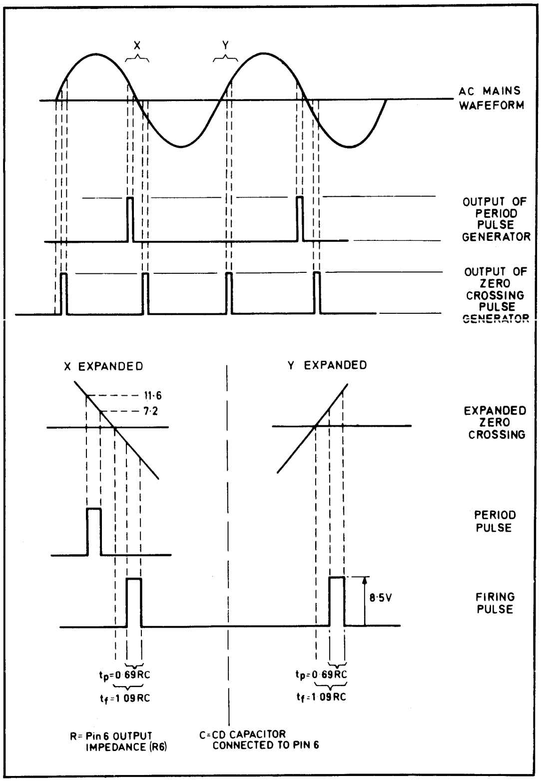
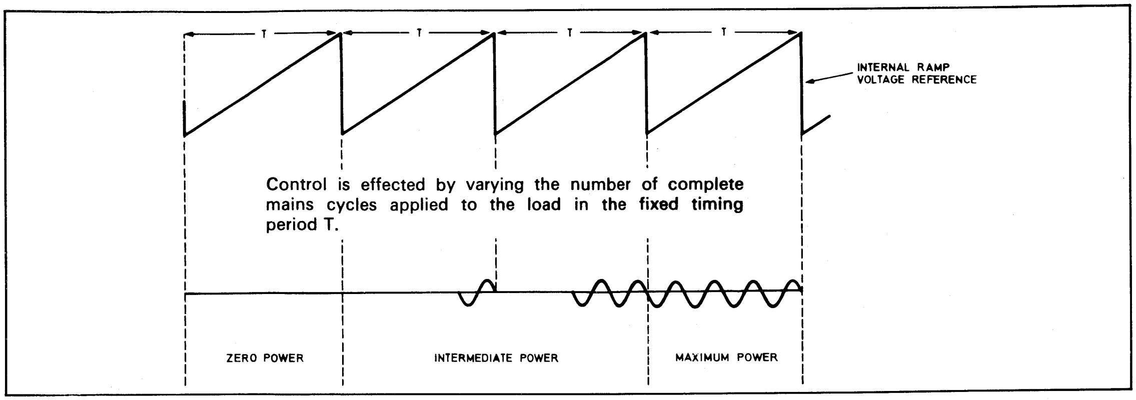
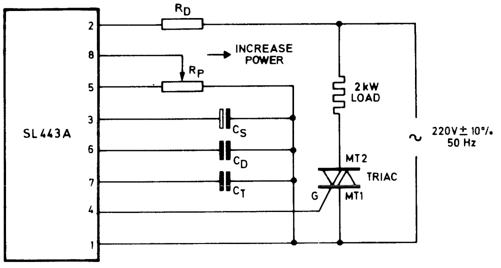


Fig. 4 Method of control



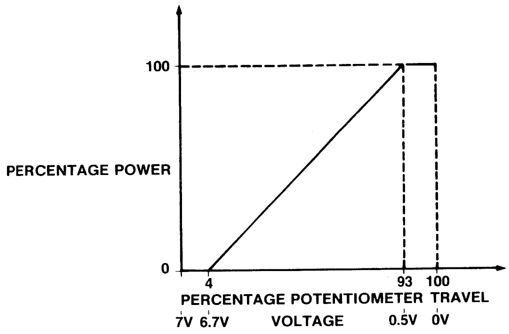
Control is effected by varying the number of complete mains cycles applied to the load in the fixed timing period T.

Fig. 5 Method of control



Component values
R_D 8.2kΩ 5% 7W
R_P 100kΩ (Control characteristic of linear potentiometer is shown in Fig. 7)
C_S 220μF 16V
C_T 0.47μF (Ramp period = 20 seconds nominal)
C_D 1.5nF ±10%
TRIAC TAG.255 – 400

Fig. 6 Cooker hotplate control

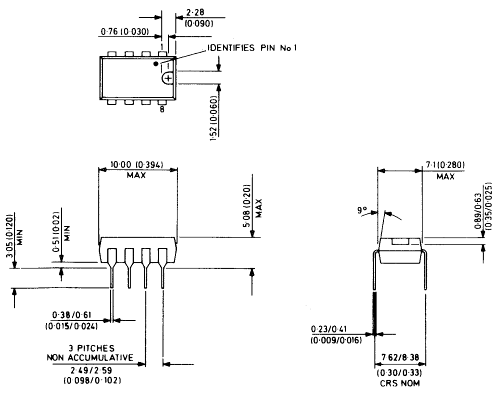


This characteristic applies to a linear potentiometer. Different control characteristics are easily obtained by using a non-linear potentiometer and/or offset resistors in the potentiometer circuit.

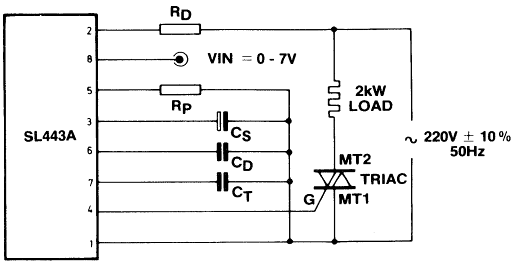
Fig. 7 Output power v. potentiometer displacement or voltage on pin 8

PACKAGE DETAILS

Dimensions are shown thus: mm (in)



8 LEAD PLASTIC DIL **DP8**



Component values
R_D 8.2kΩ 5% 7W
R_P 100kΩ
C_S 220μF 16V
C_T 0.47μF (Ramp period = 20 seconds nominal)
C_D 1.5nF ±10%
TRIAC TAG.255 – 400

Fig. 8 Voltage control

PLESSEY
Semiconductors

SL445A

ZERO VOLTAGE SWITCH

The SL445 is a triac controller providing a *complete* solution for temperature controlled electric panel heaters, cookers, film processing baths etc.

Switching occurs at the zero voltage point in order to minimise radio frequency interference.

The device is suitable for mains-on-line operation and requires minimal external components.

SPECIAL FEATURES

1. Choice of proportional or on/off temperature control.
2. Controlled switching rate in order to limit 'lamp flicker' (as per EN50,006). A pulse integration technique eliminates the problems associated with electrolytic timing capacitors.
3. Very accurate temperature control is possible since switching jitter has been eliminated *without introducing hysteresis* to the servo amplifier.
4. Symmetrical burst control i.e. no half-wave firing (as per EN50,006).
5. LED drive circuit which responds directly to the temperature setting.
6. Over-temperature protection circuit using a 'fail-safe' PTC thermistor and having the option of automatic or manual reset.
7. LED/Buzzer drive circuit controlled by 6 above.
8. High immunity against spurious triac trigger pulses under noisy mains environment.
9. Spurious triac trigger pulses inhibited at 'switch-on'.
10. Potentiometer expansion circuit to improve resolution/reduce component count.

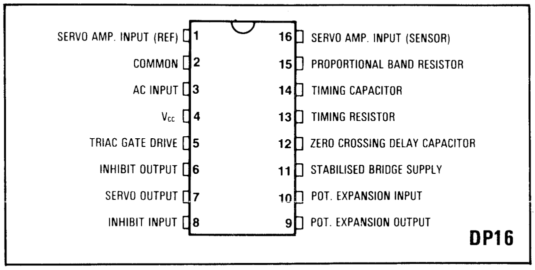


Fig.1 Pin connections - top view

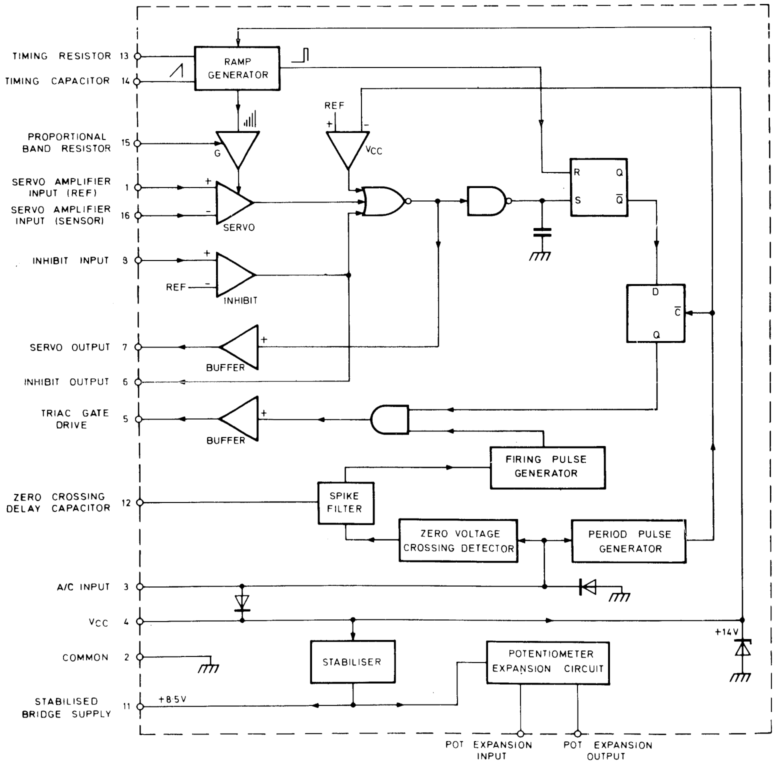


Fig.2 SL445A block diagram

CIRCUIT DESCRIPTION

The externally current limited AC supply is applied to the device and rectification followed by shunt regulation produces a 14V DC supply.

This is externally smoothed before application to the 8.5V series stabiliser which must be within regulation or operation of the 'Low Vcc Inhibit' circuit will result. This latter circuit overrides all other circuitry and prevents unsuitable firing pulses from being supplied to the triac at 'switch-on'. The current limited AC supply also drives the Period Pulse Generator (PPG) and Zero Voltage Crossing circuits.

The PPG produces a single short duration pulse for each completed mains cycle and serves two purposes. Firstly it is used to clock logic information such that the circuit behaves in a symmetrical manner and only complete mains cycles are applied to the load. Secondly the pulse is used to switch timing components in the ramp generator and this enables long time constants to be achieved without having to resort to the use of electrolytic capacitors.

The Zero Voltage Crossing Detector controls a pulse generator that has a delayed output. This delay is necessary since with loads that are slightly inductive or low power resistive, the triac load current may not reach its required holding level at the zero voltage point.

Both delay and pulse duration are defined by an external capacitor and this further serves the purpose of filtering out spikes which occur in the zero crossing region. Automatic rejection takes place of spikes having a duration of up to 50 per cent of the normal width of the triac firing pulse.

The Servo Amplifier has differential inputs and these are used to sense the output of the bridge containing the room temperature sensing thermistor. The output of this amplifier is NOR-gated with the outputs of the Inhibit Amplifier and the Low Vcc Amplifier.

The output of this gate is accessible such that it may be used to control an LED so indicating whether or not the appliance is consuming electricity .The output from the NOR gate is also applied to an active spike filter before application to the S input of the R/S Bistable. Since this bistable can only be reset once every ramp generator cycle, it follows that a definite limitation is imposed on the switching rate of the system and this enables compliance with the requirements of the EN50-006 regarding 'lamp-flicker'.

An externally defined proportion of the ramp waveform may be applied to the 'offset' of the Servo Amplifier such that the amplifier has an offset which varies linearly with time. This has the effect – as the bridge approaches balance – of varying the power output in proportion to the difference between the set temperature and the actual temperature i.e. Proportional Control. The advantage of this arrangement is that the approach of bridge balance is anticipated and overshoot is avoided.

The potentiometer expansion circuit matches the characteristics of a typical NTC thermistor to provide good resolution and linear temperature control over the normal domestic temperature range.

The Bridge is supplied with a stable 8.5V supply from the series stabiliser and one ninth of this supply is used as a reference voltage for the Inhibit Amplifier. This reference is compared with the voltage appearing across the PTC thermistor which is used to sense an overtemperature condition. The output of the Inhibit Amplifier is used to control the NOR gate which has already been mentioned and is also made accessible such that visual or audible warning may be provided. In addition, a suitable resistor may be connected between amplifier input and output to provide hysteresis should this be required. Choice of resistor value will determine whether the circuit works in an automatic or manual reset mode.

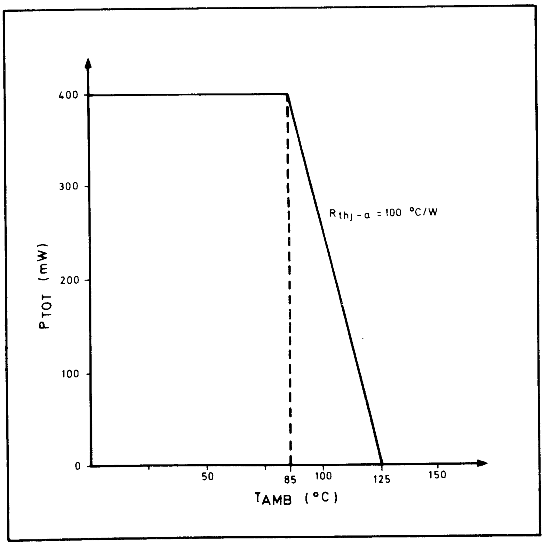


Fig. 3 Power dissipation

ABSOLUTE MAXIMUM RATINGS

Pin	Max.	Units
1. Applied voltage	V_4	V
3. Peak Repetitive Current in ($\pm I_{2M}$)	80	mA
3. Non-repetitive peak current (tp $<250\mu S$) $\pm I_{2SM}$	200	mA
5. Applied voltage	10	V
6. Applied Voltage	10	V
6. Output Current	10	mA
7. Applied Voltage	6	V
7. Output Current	10	mA
8. Applied Voltage	10	V
9. Applied Voltage	V_{11}	V
10. Applied Voltage	V_{11}	V
11. Output Current	10	mA
16. Applied Voltage	V_4	V

ELECTRICAL CHARACTERISTICS

Operating temperature range −10°C to + 85°C
Storage temperature range −55°C to +125°C

Test conditions (unless otherwise stated):
$T_{amb} = 25°C$
All potentials measured with respect to common (pin 2)

Characteristic	Value Min.	Typ.	Max.	Units	Conditions
Shunt regulating voltage Pin 4		14.7		V	$I_4 = 20mA$ average
Max. regulating voltage on Pin 4 at 85°C			16	V	$I_4 = 20mA$ average
Supply sensing amplifier – minimum working voltage Pin 4		12.2		V	
Quiescent current drain ★			8.2	mA	Less I_{11}, I_7, I_6, I_{5AV}
Stabilised bridge supply voltage Pin 11 @ 2mA	8.0	8.5	9.0	V	
Temperature coefficient Pin 11	−1		+1	mV/°C	
Triac gate drive Pin 5					See Fig. 7 for pulse timing
Open circuit OFF voltage			0.1	V	
Open circuit ON voltage		8.5		V	
Current drive into short circuit			200	mA	
Current drive into 2V drain	80	100		mA	
Current drive into 4V drain	50	70		mA	
Internal drain resistance Pin 5		800		Ω	
Servo amp. Pins 1 & 16					
Input bias current			1	µA	
Input working voltage range	0		10	V	
Servo amp. output voltage drive Pin 7	6.0	6.5	7.0	V	
Internal drain resistance Pin 7	10	25	60	kΩ	
Inhibit amp. input Pin 8					
Trip voltage	0.9	0.95	1.0	V	$V_{11} \div 9$
Input bias current			1	µA	
Input working voltage range	0		10	V	
Inhibit amp. output voltage drive Pin 6	5.8	6.4	6.8	V	
Internal drain resistance Pin 6	8	12	16	kΩ	
Inhibit voltage Pin 6		3.5		V	
Potentiometer expansion circuit input bias current Pin 10			10	µA	See Fig. 8
Potentiometer expansion circuit output resistance Pin 9	4	6	8	kΩ	See Fig. 8
Proportional control band ($R_{15} = 220k$)	60	100	140	mV	$R_{15} = 220kΩ$
Ramp generator period T	40	44	48	s	$R_{13} = 100k$, $R_{14} = 1.0µF$, 220V AC

★ The supply current is 0.45 × (RMS current fed into Pin 3)

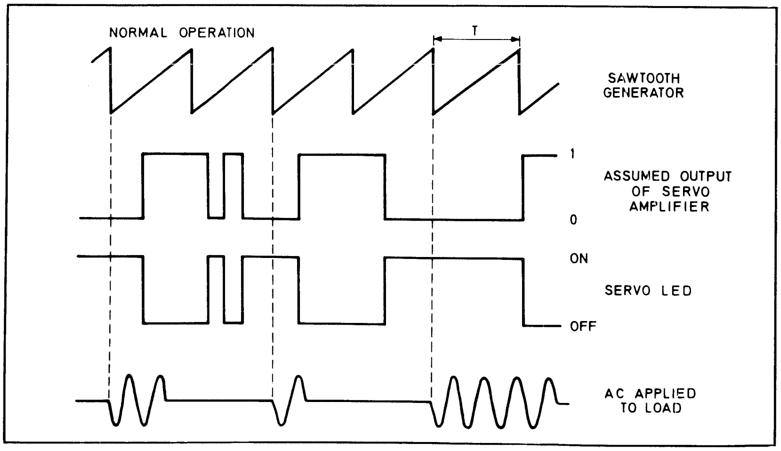


Fig. 4 Timed on/off control

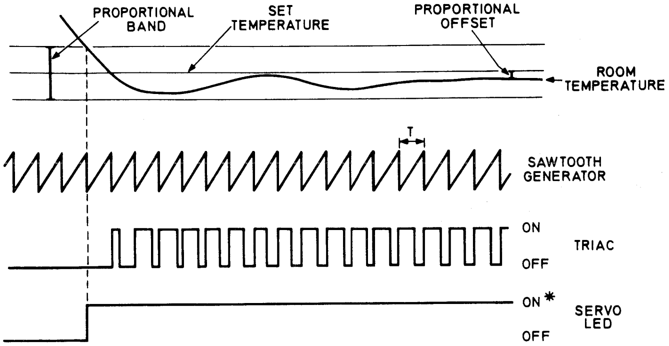
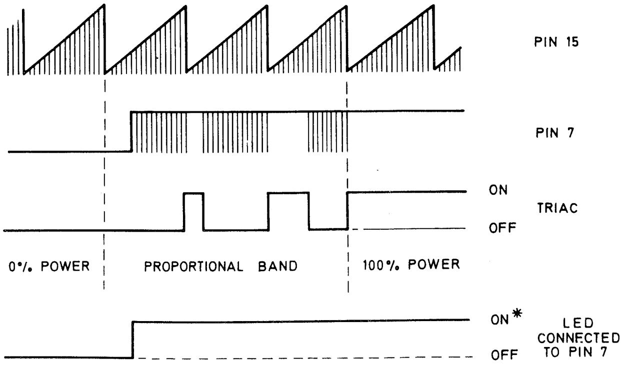


Fig. 5 Timed proportional control normal operation



* THE SHORT DURATION INTERRUPTIONS IN LIGHT OUTPUT ARE NOT REGISTERED BY THE EYE.

Fig. 6 Timed proportional control (expanded)

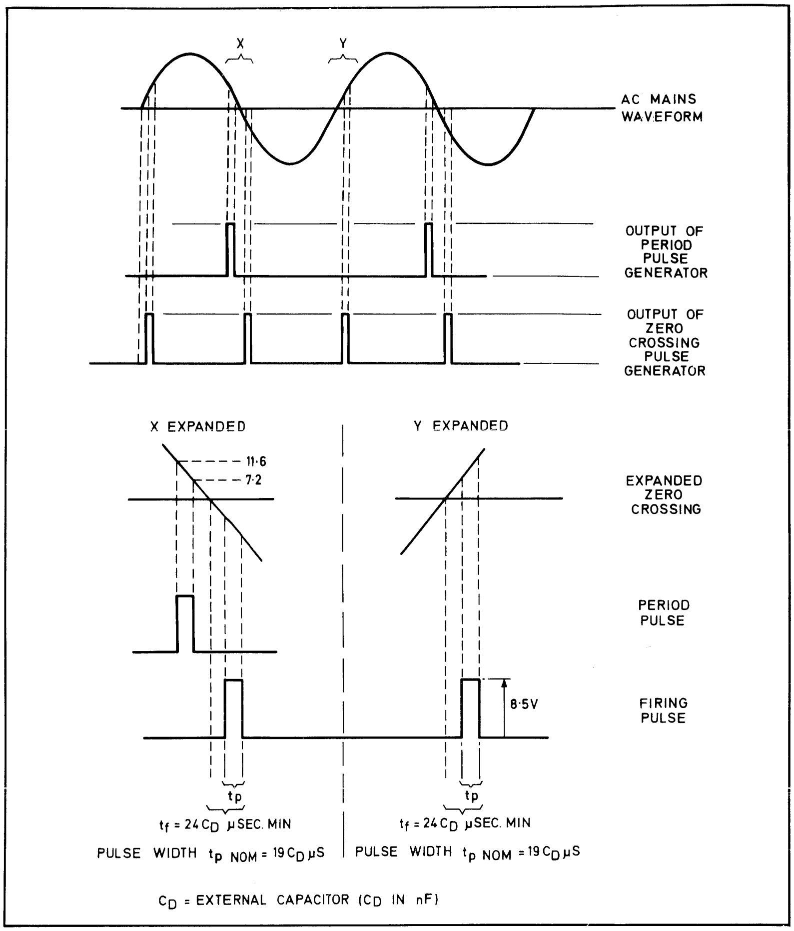


Fig. 7 Pulse timing

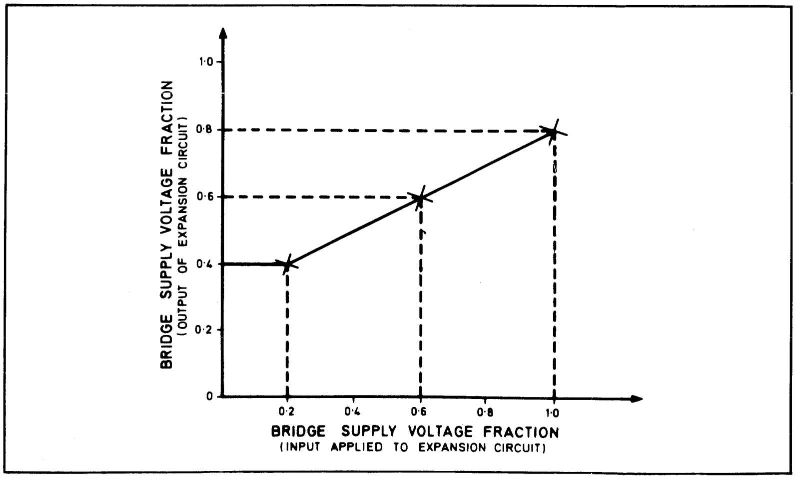
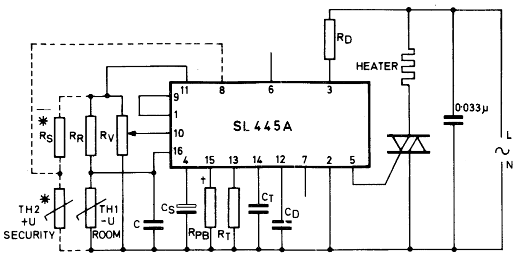


Fig. 8 Potentiometer expansion characteristic



* These two components may be omitted if the over-temperature trip facility is not required. Pin 8 should then be taken to common ie. Pin 2.

† This component may be omitted if proportional control is not required. The circuit will then provide time on/off control. Pin 15 should be taken to Pin 11.

C May be required to integrate input noise e.g. 47nF.

Fig. 9 Electric panel heater control with room thermostat and optional security thermostat

LED INDICATOR

Provides the following facilities

(a) In the case of timed proportional control, the LED will be lit continuously if any energy is supplied during the timing cycle, i.e. the LED will only be extinguished if the room temperature is being maintained without panel assistance.

(b) In the case of timed on/off control, the LED will be lit for the period that energy is being consumed, i.e. the LED will flash on and off as the room temperature varies about the set point.

(c) Room temperature may be ascertained by observing LED action whilst adjusting the temperature setting i.e. the LED is a substitute for the sound produced by electromechanical thermostats.

The LED facility may be added as shown in Fig. 10.

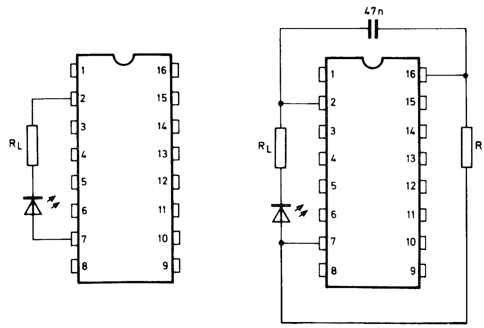


Fig. 10a Simple indicator *Fig. 10b Flicker-free indicator*

Fig. 10 LED indicator connections

It is desirable to minimise LED drive current since this has a significant effect on the power rating of the mains dropping resistor R_D. If the LED is for facility 'a' or 'b', a high intensity, wide viewing angle LED will be required and a current of 5mA nominal is suggested i.e. $R_L = 1k\Omega$ ($V_{LED} = 1.5V$).

If the LED is only intended for facility 'c', a small, narrow viewing angle LED may be used and a current of 0.5mA nominal is sufficient i.e. $R_L = 10k\Omega$ ($V_{LED} = 1.5V$).

A small amount of positive feedback may be applied to the servo amplifier by inclusion of resistor Rf (Fig. 106). This can ensure flicker free operation of the LED by increasing the immunity of the amplifier to noise etc. on its input connections. However, the level of feedback should be minimised since temperature regulation will necessarily be impaired. A typical value for Rf would be 4.7 MΩ and this results in a hysteresis of 13mV (0.13°C) if the bridge components are as given below.

SECURITY (OVERTEMPERATURE TRIP) INDICATION

Indication may be provided by LED or buzzer as shown in Fig. 11.

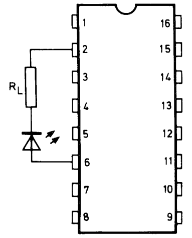


Fig. 11a LED ($I_{LED} = 5mA$, $V_L = 1.5V$, $R_L = 1k\Omega$; $I_{LED} = 0.5mA$, $V_L = 1.5V$, $R_L = 10k\Omega$)

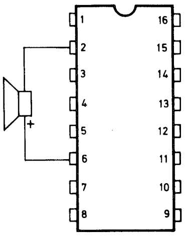
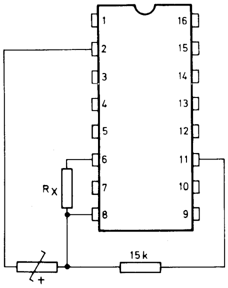


Fig. 11b Buzzer (6V, 6mA)

Fig. 11 Security indicator circuits

SECURITY (OVERTEMPERATURE TRIP) RESET

Hysteresis may be externally applied to the Inhibit Amplifier such that re-entry of the control circuit takes place automatically i.e. when the panel temperature falls to a certain level below the trip point. Alternatively, it may be arranged that the trip circuit – when activated – can only be reset by manual intervention e.g. momentarily interrupting the mains supply. It is desirable to introduce some hysteresis to the system when using a buzzer, in order to ensure positive on/off operation. When the manual reset mode of operation is adopted, an additional capacitor is required to eliminate the possibility of a spurious spike tripping the circuit.



R_x = 120k reset occurs 1°C below the trip point.
R_x = 56k reset occurs 2°C below the trip point.
(Above assumes that the PTC thermistor has a +15%/°C coefficient in the region of the trip temperature e.g. the ITT positte range.)

Fig. 12 Automatic reset

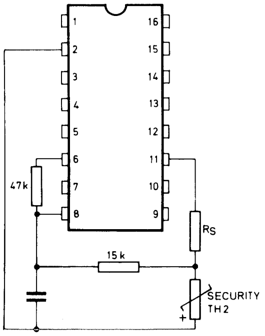


Fig. 13 Manual reset

COMPONENT VALUES

Room Temperature Sensing (R_R, TH1, R_V)

R_V = 22k or 25k linear control potentiometer.
R_R = 18k ±2%
THI = NTC thermistor, e.g. ITT type KQ223Y,
R_{25} = 22k ±10%, B = 4300 ±5%

Using these components, substantially linear temperature control is obtained over the range 5°C to 35°C. This range is covered by 69% of the potentiometer track when the I.C's expansion circuit is used as shown in figure I. If the LED facility is used, calibration can be both accurate and rapid.

Controlled Switching rate (R_T, C_T)

The period of the ramp generator is dictated by the requirements of Cenelec EN50.006 concerning lamp flicker. The load can only be switched into circuit at the start of a ramp cycle i.e. if power is interrupted to the load at any point in the cycle, subsequent demands for power can only be met at the start of the next cycle.

The pulse integration technique employed in the ramp generator accounts for the mains voltage term in the formula:

Period of ramp $= 0.2 \times V_{RMS} \times C_T$ seconds ±10%

This assumes $R_T = 100\text{k}$. C_T is in μF, and V_{RMS} is in volts, e.g. a 1.0μF capacitor will provide a ramp period of 44 sec if the circuit is used with a 220V AC supply.

The capacitor should be of polyester or similar construction. Because of leakage and other considerations, electrolytic capacitors are not suitable.

Proportional Control (R_{PB})

Resistance R_{PB} controls the proportion of the ramp waveform which is applied internally to the offset facility of the servo amplifier. R_{PB} therefore, controls the width of the proportional control band.

If R_{PB} = 220k, the peak offset will be 100mV which is equivalent to a proportional control band of 1°C if the above bridge component values are used.

If R_{PB} = 100k, PB = 2.2°C
= 390k, PB = 0.55°C etc.

Overtemperature Control (Security) (R_S, TH2)

R_S = 15k

	Trip Temperature Min.	Trip Temperature Max.
TH2 = ITT POSITTE PTC thermistor type YC080TB	82°C	90°C
= ITT POSITTE PTC thermistor type YC090TB	92°C	100°C
= ITT POSITTE PTC thermistor type YC100TB	102°C	110°C

Thermistors of alternative manufacture may be used although the value of Rs may then differ. Tripping takes place if the resistance of TH2 is greater than $R_S \div 8$.

The value of Rs should be kept high to minimise power loss in R_D.

Triac and C_D

Generally, the maximum gate firing voltage (V_{GT}) of a triac is 2.0V and the output stage of the IC has been designed to deliver a minimum of 80mA into such a load. The nominal current is 100mA and the triac is supplied with positive gate current. A wide range of suitable, low price triacs are available from several manufacturers. In order to minimise RFI, a triac should be chosen which has a low latching current I_L. The triac cannot latch until the supply voltage $V_L \geqslant (V_T + I_L \times R_L)$ where

V_T = on-state voltage of the device
R_L = resistance of the triac load

Therefore the triac requires a gate current

$$\frac{V_L \times 10^6}{V_{RMS} \times \sqrt{2} \times 2\pi f}\ \mu s$$

after the zero crossing point in the supply cycle where

f = the supply frequency.
e.g. for a 380V ±10%, 50HZ supply, 1kW load
MAX. V_T of triac = 1.2V (@ I_L)
MAX. I_L of triac = 50mA

$$\text{we get } R_L = \frac{380^2}{10^3} = 144.4\Omega$$

$$R_L \text{ MAX} = 144.4 + 5\% = 152\Omega$$

$$V_L = I_L \times R_L + V_T = 0.05 \times 152 + 1.2 = 8.8\text{V Max}$$

The trailing edge of the firing pulse (Tf) must occur not sooner than

$$\frac{V_L \times 10^6}{V_{RMS} \times \sqrt{2} \times 2\pi f}\ \mu\text{s after the zero crossing point.}$$

$$\text{Tf MIN.} = \frac{8.8 \times 10^6}{0.9 \times 380 \times \sqrt{2} \times 2 \times \pi \times 50}$$

$$= 57.91\ \mu\text{s} = 24 \times C_D$$

$$\therefore\ C_D \text{ MIN.} = 57.91 = 2.41 \text{ nF}$$

$$\therefore\ C_D = 2.7 \text{ nF} \pm 10\%$$

The same triac could of course be used to control a higher power load. The load resistance and hence required V_L would fall, but for convenience the value of C_D need not be altered. Similarly, if the above calculations are repeated for a 220V supply, it will be established that C_D must exceed 1.77 nF and a value of 2.7 nF is again suitable. It may be convenient to use the same triac and value of C_D for 220, 240 and 380V applications. However, C_D should be kept as low as possible if power dissipation in the dropper resistor is to be minimised.

MAINS DROPPING RESISTOR (R_D)

Table I indicates the value of resistor R_D as a function of mains supply voltage, facilities provided etc. It will be apparent that it is desirable when dealing with a 380V supply to reduce power dissipation in the dropper resistor by introducing a series diode.

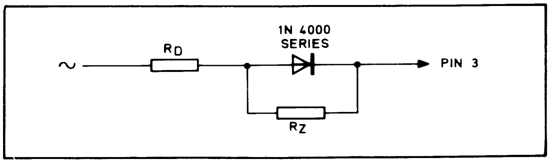


Fig. 14 Mains supply input circuit

	110V	220/ 240V	380V
R_Z ±10%	39k	82k	82k
Power dissipation in R_Z (max)	0.3W	0.4W	1W
Minimum value C_D	2.4 nF	1.9 nF	1.3 nF

Table 2 Max. value of R_Z for various supply voltages

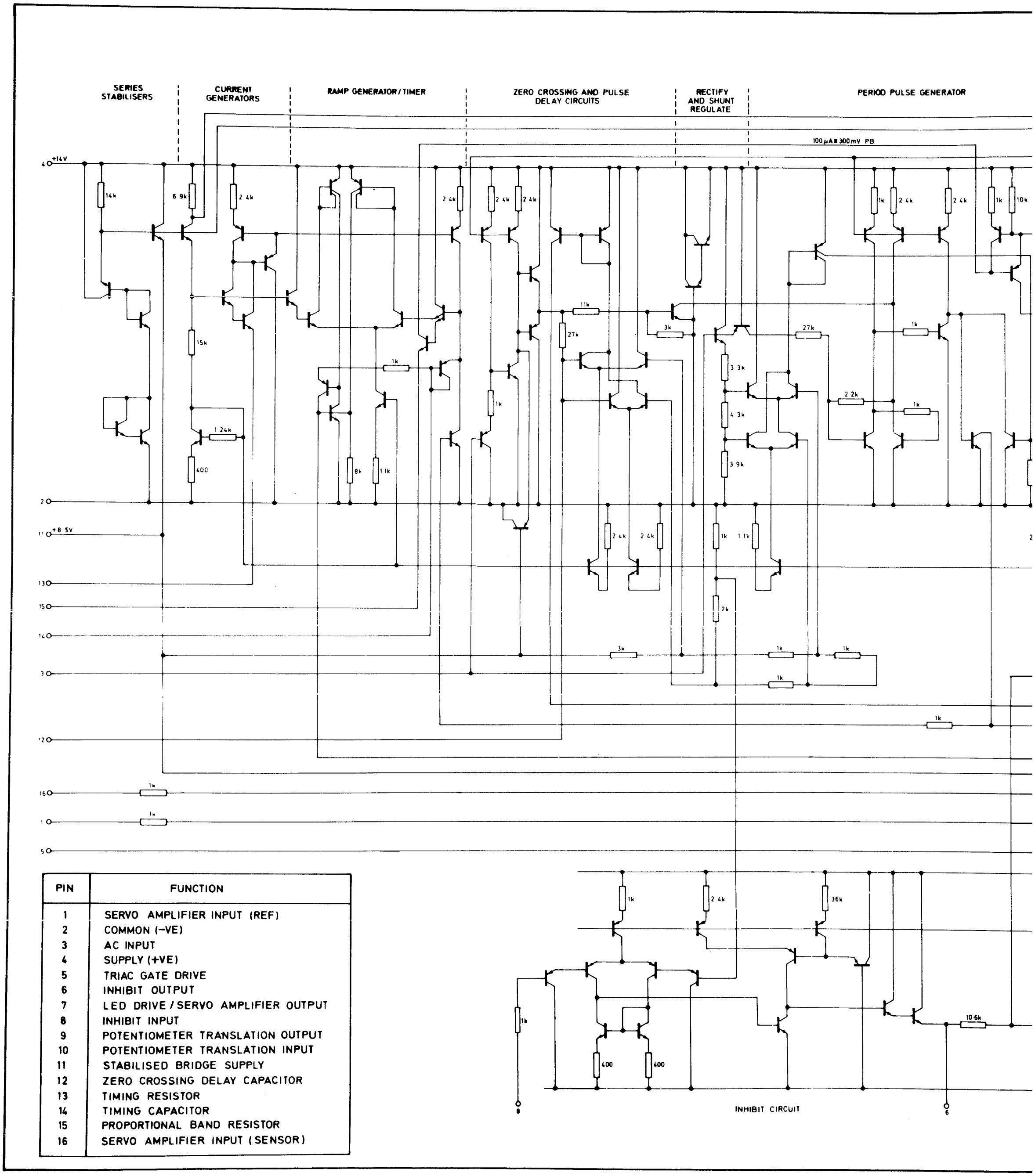
The diode bypass resistor R_Z (see Table 2) is necessary to provide proper operation of the zero voltage crossing circuit. The values for R_D given in the table may be reduced for rationalization purposes if required (e.g. common value for 220/240V supplies) or where additional external circuitry is fed by the 8.3V or 14V supplies. This may necessitate an appropriate increase in the value of the smoothing capacitor Cs. Furthermore, consideration should be given to the possible increase in chip power dissipation particularly if the external load is dynamic.

SMOOTHING CAPACITOR (Cs)

A 220μF 16V Capacitor should be used except when dealing with the higher current applications i.e. 5mA LED, 6mA buzzer etc. Cs should then be increased to 330μF. The ripple voltage should be kept below 1V peak – to – peak.

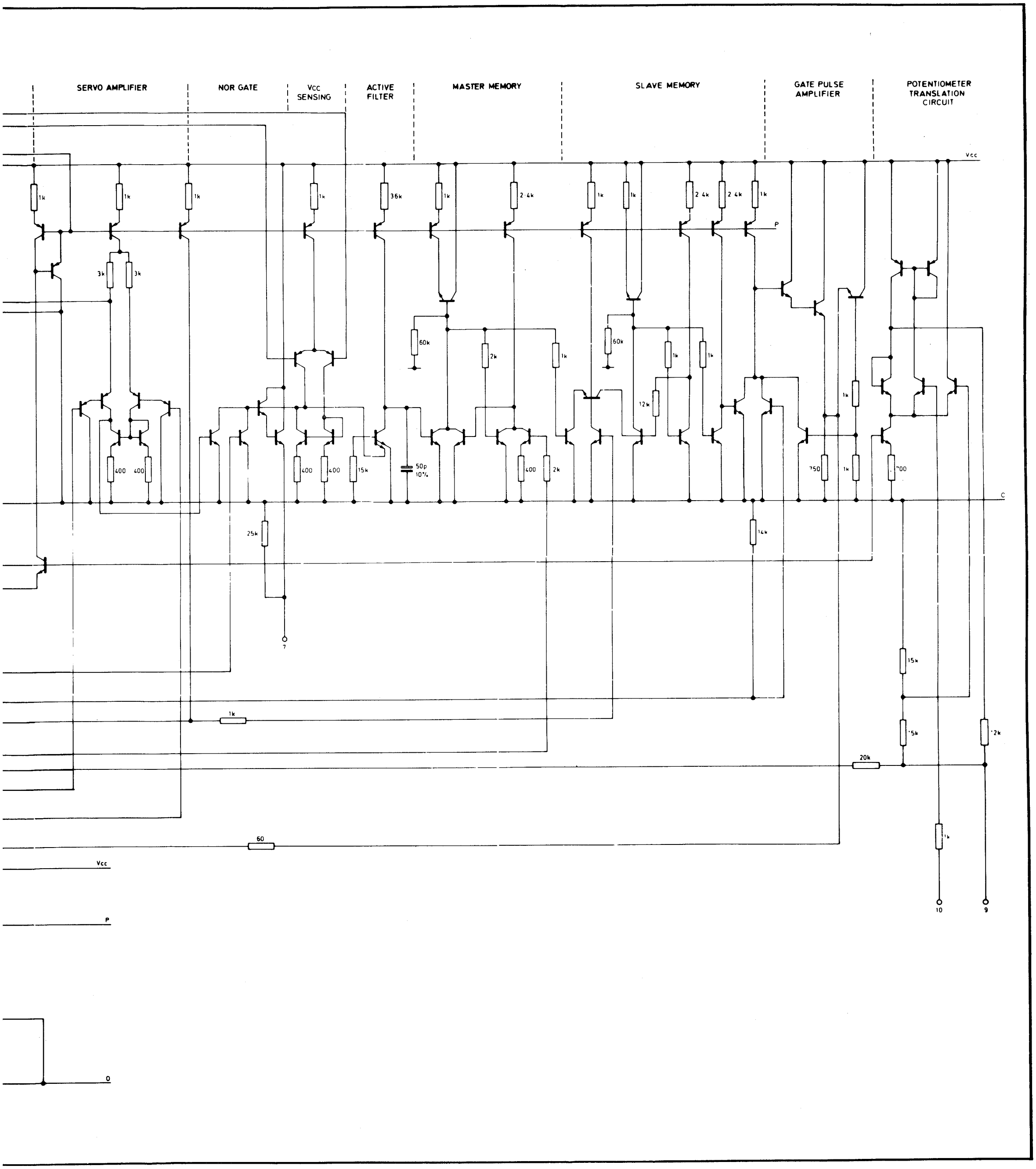
Facilities used					Nominal R_D value (±5%)	Maximum R_D power dissipation	Maximum R_D power dissipation (with diode)	Nominal power supply voltage ±10%	Nominal C_D
Room temperature control	Servo LED 0.5mA	Over temperature trip (security)	Servo LED 5mA	Security buzzer (6V, 6mA)					
●					3.3k	4.7W	2.3W	110V	4.7nF
●					7.5k	8.2W	4.1W	220V	2.7nF
●					8.2k	8.9W	4.4W	240V	
●					12k	15.3W	7.6W	380V	
●	●				3.0k	5.1W	2.5W	110V	4.7nF
●	●				6.8k	9.1W	4.5W	220V	2.7nF
●	●				7.5k	9.8W	4.9W	240V	
●	●				12k	15.3W	7.6W	380V	
●		●			3.0k	5.1W	2.5W	110V	4.7nF
●		●			6.8k	9.1W	4.5W	220V	2.7nF
●		●			7.5k	9.8W	4.9W	240V	
●		●			12k	15.3W	7.6W	380V	
●	●	●			3.0k	5.1W	2.5W	110V	4.7nF
●	●	●			6.8k	9.1W	4.5W	220V	2.7nF
●	●	●			7.5k	9.8W	4.9W	240V	
●	●	●			12k	15.3W	7.6W	380V	
●			●		2.2k	7.0W	3.5W	110V	4.7nF
●			●		5.1k	12.1W	6.0W	220V	2.7nF
●			●		6.2k	11.8W	5.9W	240V	
●			●		9.1k	20.2W	10.1W	380V	
●		●	●	●	2.2k	7.0W	3.5W	110V	4.7nF
●		●	●	●	4.7k	13.1W	6.5W	220V	2.7nF
●		●	●	●	5.1k	14.4W	7.2W	240V	
●		●	●	●	8.2k	22.4W	11.2W	380V	

Table 1 Value of R_D (mains dropping resistor)



PIN	FUNCTION
1	SERVO AMPLIFIER INPUT (REF)
2	COMMON (-VE)
3	AC INPUT
4	SUPPLY (+VE)
5	TRIAC GATE DRIVE
6	INHIBIT OUTPUT
7	LED DRIVE / SERVO AMPLIFIER OUTPUT
8	INHIBIT INPUT
9	POTENTIOMETER TRANSLATION OUTPUT
10	POTENTIOMETER TRANSLATION INPUT
11	STABILISED BRIDGE SUPPLY
12	ZERO CROSSING DELAY CAPACITOR
13	TIMING RESISTOR
14	TIMING CAPACITOR
15	PROPORTIONAL BAND RESISTOR
16	SERVO AMPLIFIER INPUT (SENSOR)

Fig. 15 C


SERVO AMPLIFIER
NOR GATE
Vcc SENSING
ACTIVE FILTER
MASTER MEMORY
SLAVE MEMORY
GATE PULSE AMPLIFIER
POTENTIOMETER TRANSLATION CIRCUIT
Vcc
P
C
1k
1k
1k
1k
36k
1k
2·4k
1k
1k
2·4k
2·4k
1k
3k
3k
60k
2k
1k
60k
1k
1k
12k
1k
400
400
400
400
15k
50p 10%
400
2k
750
1k
700
25k
14k
7
1k
15k
5k
2k
20k
60
1k
10
9
Vcc
P
0

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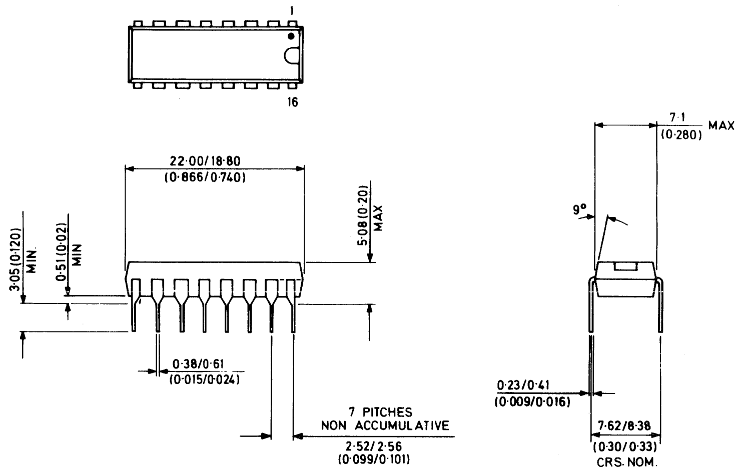
PACKAGE DETAILS

Dimensions are shown thus : mm (in)



16 LEAD PLASTIC DIL **DP16**

PLESSEY Semiconductors

TDA1085C

PHASE CONTROL INTEGRATED CIRCUIT

The TDA1085C is a silicon integrated circuit designed for use in phase control systems of AC mains with resistive and inductive loads. The circuit may form the basis of closed loop control systems utilizing tacho frequency or analogue voltage feedback.

The circuit was primarily designed for motor speed control in automatic washing machines and hence includes a programmable multiple ramp generator to control acceleration rates.

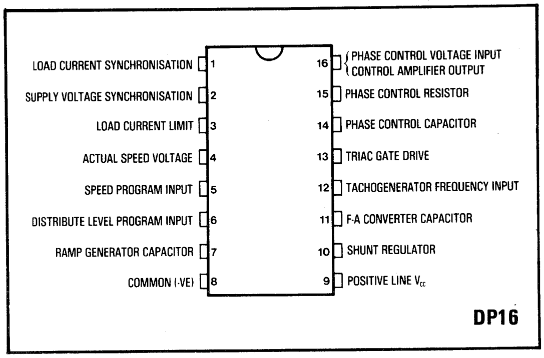


Fig.1 Pin connections - top view

SPECIAL FEATURES

- Powered direct from AC mains or DC line.
- Flexible ramp generator to provide controlled acceleration and distribution period.
- Actual speed derived from tachogenerator frequency or magnitude.
- Control amplifier allowing loop gain control.
- Symmetrical positive and negative wave firing of the triac.
- Motor current limiting.
- Fail safe in case of open circuit tachogenerator.
- Repeated triac pulses provided if triac unlatches.

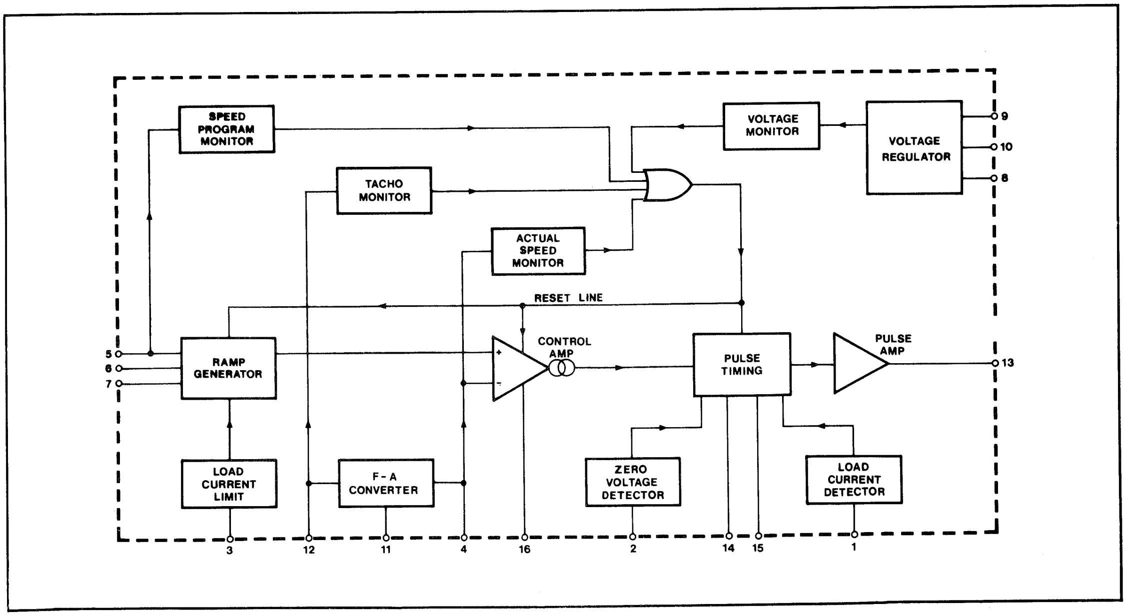


Fig.2 Block diagram of TDA1085C

ELECTRICAL CHARACTERISTICS

Test conditions (unless otherwise stated):
$T_{amb} = +25°C$
All potentials measured with respect to common (Pin 8)

Characteristic	Value			Units	Conditions
	Min.	Typ.	Max.		
CURRENT CONSUMPTION					
Pin 9					
IC operating current		7.4	8.9	mA	Total current required is dependent on external circuitry.
VOLTAGE REGULATOR					
Pin 9					
Shunt regulating voltage		15.5	16	V	$I_9 + I_{10} = 10mA$
Monitor enable level		15.1		V	
Monitor disable level		14.5		V	
RAMP GENERATOR (See Fig.3)					
Pin 7					
Fast ramp current		1.2		mA	
Residual charging current		5		μA	During slow ramp period
Pin 5					
Speed program voltage range	0.08		13.5	V	
Bias current			-20	μA	
Pin 6					
Program distribute level	0		4	V	
Bias current			-20	μA	
Internal					
Low distribute level V_{RA}		V_6	1.2	V	Distribute levels referred to ramp generator.
High distribute level V_{RB}	$1.9V_6$	$2V_6$	$2.1V_6$	V	
FREQUENCY-ANALOGUE CONVERTER					
Pin 12					
Positive tacho input voltage			6	V	
Negative tacho input voltage			-3	V	
Minimum tacho input voltage	200			mV	Peak-Peak
Internal bias current		25		μA	
Pin 12 to Pin 11					
Conversion factor (typical)		7.5		mV/Hz	C pin 6 = 390pF,R pin 4 = 150kΩ
		15		mV/Hz	C pin 6 = 820pF,R pin 4 = 150kΩ
Conversion gain		10			
Linearity		±4		%	
CONTROL AMPLIFIER					
Pin 4					
Actual speed voltage limits	0		13.5	V	
Analogue input bias current			-350	nA	
Pin 4, 5 & 16					
Differential offset voltage	-60		+20	mV	$V_5 - V_4$ to give $I_{16} = 0$
Transconductance		300		μA/V	
Pin 16					
Output current drive		±100		μA	
FIRING PULSE TIMING					
Pin 2					
Voltage sync trip level		±50		μA	
Pin 1					
Current sync trip level		±50		μA	
Pin 16					
Phase control voltage swing		11.7		V	
Pin 13					
Firing pulse width		55		μs	R pin 15 = 300kΩ
Pulse repetition time		200		μs	C pin 14 = 47nF

(continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Value			Units	Conditions
	Min.	Typ.	Max.		
Pin 14					
Ramp recharge current (I_R)		150		μA	
FIRING PULSE OUTPUT DRIVE					
Pin 13					
High output level		V_{CC} - 4		V	At 150mA drive current
Leakage current			30	μA	
LOAD CURRENT LIMITER					
Pin 3 & Pin 7					
Current gain		170	—		Reset of ramp generator
Pin 7					
Discharge current		35		mA	

CIRCUIT DESCRIPTION

The TDA1085C incorporates a shunt type voltage regulator which enables it to be powered direct from the mains or from a DC supply. It can provide adequate current to drive external speed reference potential dividers that may be switched by contacts on mechanical timers. A supply monitor circuit resets timing functions and inhibits triac firing pulses when the circuit is being powered up at 'switch on'.

A ramp generator is provided to control the acceleration of the motor, to a speed as programmed on the speed program input, pin 5. If this pin becomes grounded a general reset and inhibit of triac pulses will take effect. A programmable period of slow acceleration may be used to give a 'distribution' period for automatic washing machines. Charging currents for the ramp generator are determined by an external resistor for the slow ramp period and internally during the fast ramp.

A frequency to analogue (F-A) converter is provided on this device enabling advantage to be taken of tachogenerator frequency to be used for motor speed sensing. The conversion is carried out by transferring a pulse of charge (defined by the F-A converter capacitor) into an RC filter when the tacho input goes positive. An internal bias current is provided to the input pin; this serves two purposes: it senses the continuity of the tacho, causing a general reset and inhibit of output pulses if it goes open circuit; secondly it enables the input to be easily biased such that tacho noise causes no additional triggering of the F-A converter.

The control amplifier has differential inputs that compare the ramp generator voltage (internal) against the actual speed voltage. The output of this amplifier is a bidirectional current of limited amplitude which is integrated to limit the maximum rate of change of triac firing pulse phase angle. The actual speed voltage may be derived directly from a tacho (for analog sensing) or via the F-A converter circuit (for digital sensing). Digital sensing has the advantage that no tacho calibration is required, plus stability against temperature variations and ageing effects.

Synchronisation of the triac pulse is achieved by delaying the pulse with reference to the zero voltage points of the mains cycles. These points are determined by the voltage synchronisation input to the device. Inductive motors give rise to phase lag of the load current. Under high speed or heavy load conditions it is essential that the triac is fired after the load current from the previous half cycle has ceased. The current synchronisation pin (1) performs this task by ensuring that there is a voltage across the triac before a trigger pulse is supplied (when the triac is conducting current only a small voltage drop appears across it). The triac pulse width is dependent on the capacitor which also delays the pulse from the zero voltage point. If the triac fails to latch, repeated pulses will be supplied.

The current limitation pin (3) may be used to monitor the peak negative load current. This may be necessary to protect the triac and or motor under stall conditions. The trip point is determined by external resistors which when exceeded will cause the ramp generator to discharge to a safe working voltage.

RAMP GENERATOR CHARACTERISTIC

V_{RA} and V_{RB} are determined by the voltage programmed on pin 6 (V_6). Under all conditions $V_{RB} = 2V_6$, whereas $V_{RA} = V_6$ for $V_6 \leqslant 1.2$V but is clamped at 1.2V for $V_6 \geqslant 1.2$V.

The ramp generator output voltage only rises to the desired speed voltage as defined on pin 5.

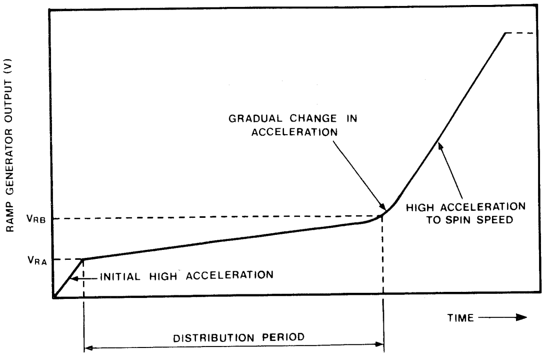


Fig.3 Ramp generator characteristic

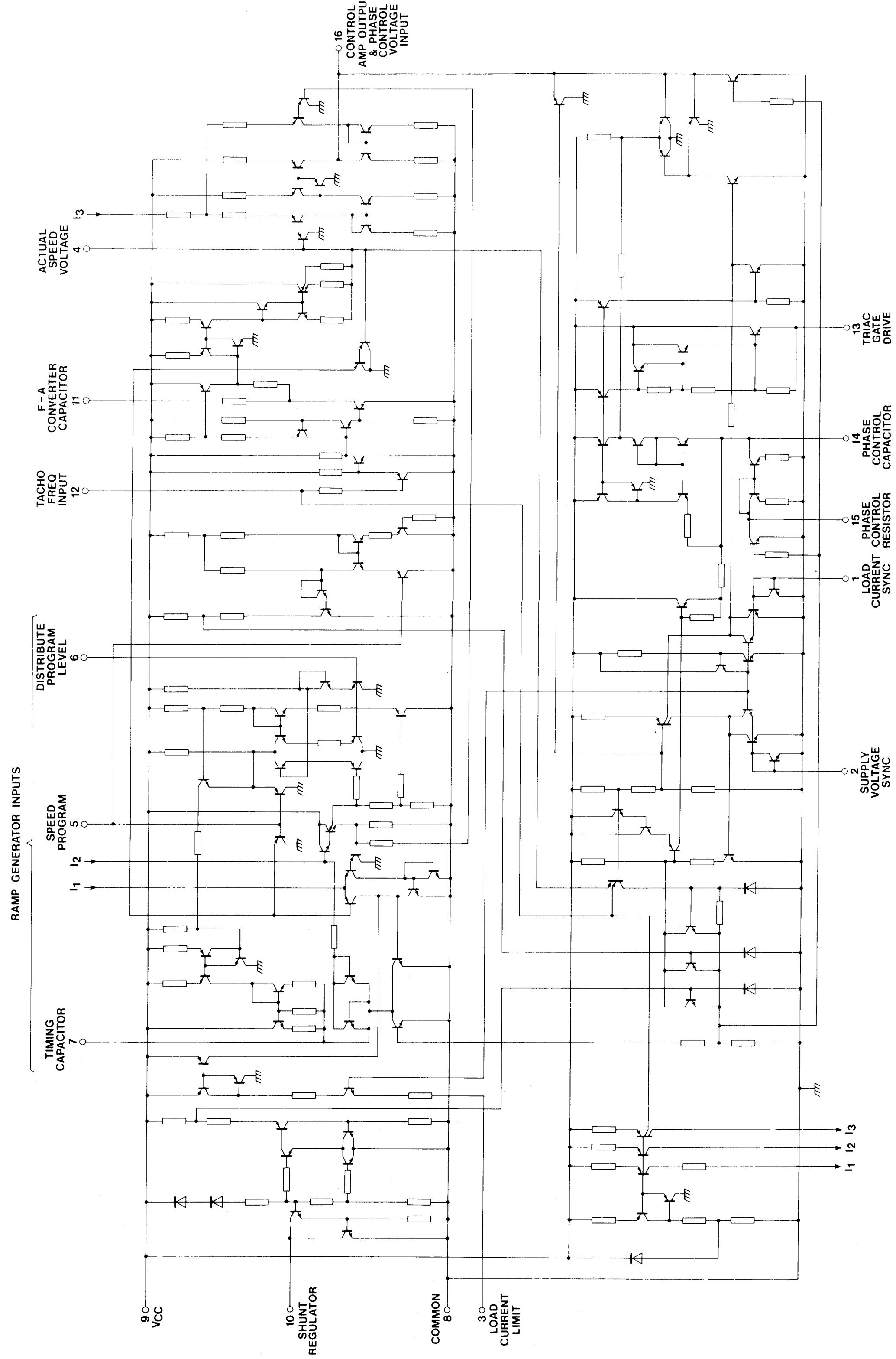


Fig.4 TDA1085C circuit diagram

ABSOLUTE MAXIMUM RATINGS

Electrical

Peak input current (I sync), pin 1:	± 2mA
Peak input current (V sync), pin 2:	± 2mA
Current drain, pin 3:	-5mA
Positive input voltage, pin 3:	6V
Analog voltage drive, pin 4:	V_{CC}
Speed reference voltage, pin 5:	V_{CC}
Distribute level, pin 6:	V_{CC}
IC Circuit current (pin 10 disconnected), pin 9:	10mA
Supply shunt regulating current, pin 10:	30mA
Tachogenerator (digital) drive input, pin 12:	-3, +0.1 mA
Triac gate current, pin 13:	200mA
Phase timing current, pin 15:	1 mA

Thermal

Operating ambient temperature:	0°C to +70°C
Storage temperature:	-55°C to +125°C

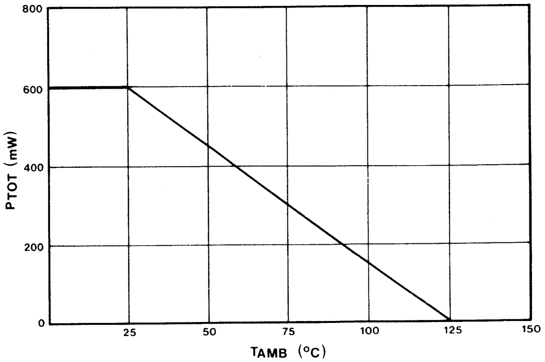
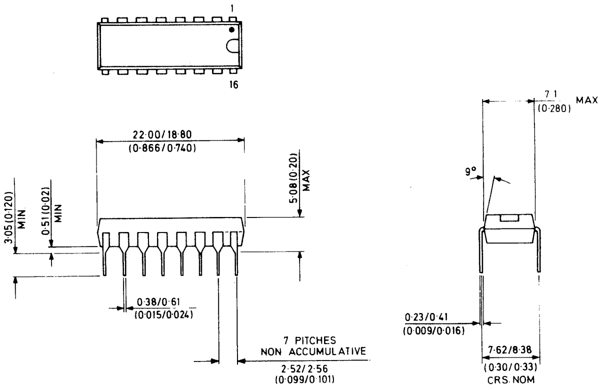


Fig.5 Power dissipation

PACKAGE DETAILS

Dimensions are shown thus: mm (in)



16 LEAD PLASTIC DIL **DP16**

System Design

Throughout this section, component references are those shown on the Reference System Circuit Diagram, Fig.6.

ANALOGUE FEEDBACK CONTROL

An analogue feedback voltage (V_f) of OV to 13.5volts, may be supplied directly to pin 4. With this type of feedback the frequency-to-analog conversion circuit should be made inoperative by connecting pin 12 to common (pin 8).

Motor speed sensing can be achieved by rectifying and smoothing a tachogenerator signal, thus generating directly an analogue feedback control voltage. It is most important with this type of system that the tachogenerator does not pick up noise signals, particularly those generated by the motor field. This may well be a problem with simple tachos incorporated inside or close to the motor, but can easily be avoided by the use of digital sensing.

DIGITAL FEEDBACK CONTROL

In this type of feedback system the frequency of an input signal to pin 12 is converted to an analogue feedback control voltage (V_f). Although digital sensing requires an extra couple of passive components it offers the advantage of not requiring any calibration of the machine, plus stability against aging and temperature effects.

The zero voltage points of an AC tacho signal are sensed at pin 12.

Without diode D2, the TDA1085C can function linearly with a range of tacho input signal levels between 0.2 and 6 volts. When D2 is included, the device will function correctly, provided the positive tacho excursion does not exceed the open circuit tacho detection voltage (13.5 volts).

An over-voltage sensing circuit will reset the timing functions and inhibit triac drive pulses if the input exceeds 13.5 volts. Providing no resistive load is placed between pin 12 and common (pin 8), a 25μA tacho monitor bias current will cause the input pin voltage to exceed this limit if the tacho goes open circuit. By this means the TDA1085C is 'fail safe' in the event of tacho circuit failure.

Due to the inductive nature of a tacho pickup coil, the current output is proportional to the operating frequency. For a wide speed control range a predominantly frequency-independent voltage may be generated by integrating the pulses by means of a capacitor. C_3 performs this function; its value is dependent on the strength of the tacho signal.

Noise pickup by the tacho may be overcome by introducing an offset voltage (V_{to}) on the input. This is easily provided by R_9 and pin 12 bias current.

$$V_{to} = R_9 \times 25 \times 10^{-3} \text{ mV} \qquad \ldots 1$$

R_9 also damps any resonance that may occur between C_3 and the tacho coil inductance.

Frequency to Analogue Conversion

The F-A converter may be used to transform the frequency derived from a tacho drive to an analogue voltage which is proportional to the motor speed. The tacho frequency is given by

$$f_t = \frac{SN}{120} \text{ Hz} \qquad \ldots 2$$

Frequency to voltage conversion is achieved by integrating a pulse of charge (at pin 4) every time the tacho input (pin 12) goes positive. This unit of charge is defined by the capacitor connected to pin 11 (C_6) and is amplified by the circuit before being integrated at pin 4.

The conversion factor (K) is determined by C_6, R_{12} and the circuit gain (A_t), which may be calculated from

$$K = 10^3 (V_{cc} - 2 V_{be}) A_t C_6 R_{12} \text{ mV/Hz} \qquad \ldots 3$$

Simplifying gives

$$K \triangleq 14 \times 10^4 C_6 R_{12} \text{ mV/Hz} \qquad \ldots 4$$

The analogue feedback voltage (V_f) generated by the converter circuit is hence given by

$$V_f = K f_t \times 10^{-3} \text{ volts} \qquad \ldots 5$$

The maximum value of V_f which occurs at the highest motor speed should be designed to be $\leqslant$ 13.5volts.

During charge transfer the internal impedance of pin 11 is approximately 100kΩ, hence the time constant of the transfer period is $10^5 C_6$ seconds. This time constant should be designed to be a fraction of the minimum positive tacho input pulse duration, in order to maintain a linear relationship between the tacho frequency and the resulting tacho feedback voltage.

C_5 is used to integrate the pulses on pin 4. To maintain linear operation of the control amplifier the ripple voltage (V_{fr}) should be made less than 200mV. Increasing the value of C_5 will reduce the ripple but will also increase the response time of the F-A converter. The ripple voltage may be calculated from

$$V_{fr} = \frac{10^3 A_t (V_{cc} - 2V_{be}) C_6}{C_5} \text{ mV} \qquad \ldots 6$$

Simplifying

$$V_{fr} \triangleq \frac{14 \times 10^4 C_6}{C_5} \text{ mV} \qquad \ldots 7$$

The temperature coefficient and performance may be improved by incorporating a 470kΩ resistor from pin 11 to Vcc. This will affect the conversion factor since this resistor will be competing with the internal (100kΩ) impedance of pin 11, for current from C6. Due to this and other component tolerances, it may be necessary to calibrate the system by means of a variable resistor on pin 4. These components are shown incorporated in Fig.13b.

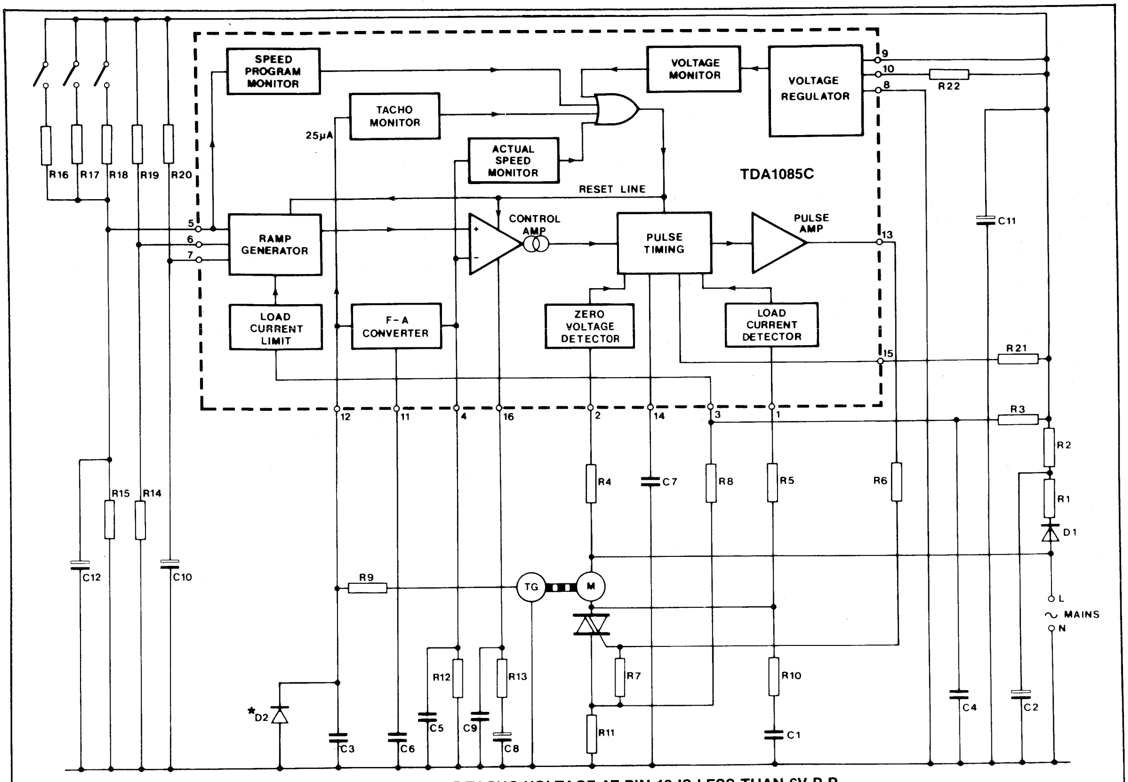
Provided the tacho input voltage at pin 12 is kept below 6V p-p then diode D2 is not required. If the tacho input voltage exceeds this, then a 1N4148 Si diode should be used to clamp the negative excursion at pin 12.

THE RAMP GENERATOR

The ramp generator's function is to limit the rate of change of the speed reference voltage (V_s) applied to the control amplifier. Providing this is the slowest time constant in a system, the amplifier will remain in a linear proportional control mode and prevent an excessive phase angle (or power) being applied to the motor load.

A programmable slow ramp period is available to enable a 'distribution period' to be provided in automatic washing machines, i.e. a controlled slow acceleration period where clothes are distributed evenly around a revolving drum prior to spin.

The ramp generator is a follower integrator design, hence the internal ramp voltage will only rise to the voltage programmed on pin 5. Due to the circuit design the ramp voltage seen on pin 7, is a V_{be} higher than the internal level at which it is monitored. If the speed program voltage is increased (e.g. from 'wash' to 'spin') then the transition is again determined by the ramp generator characteristic



✱ DIODE NOT REQUIRED IF TACHO VOLTAGE AT PIN 12 IS LESS THAN 6V P-P

Fig.6 Reference system circuit diagram

between the two programmed levels. Also if the motor speed is restrained by an overload then the internal ramp voltage is restricted from exceeding the analogue feedback voltage (V_f) by more than V_{be}.

The fast ramp current (I_{rf}) is defined by the IC and is nominally 1.2mA. This current is integrated on pin 7 by C_{10}, to produce a linear ramp. Assuming the current provided by R_{20} is negligible compared to I_{rf}, the fast ramp rate (V_{rf}) is given by

$$V_{rf} = \frac{I_{rf}}{C_{10}} \text{ mV/s} \qquad \ldots 8$$

The knee voltages of the ramp (V_{ra} and V_{rb}) are dependent on the voltage programmed on pin 6 (V_6) (see Fig.3). These two levels define the speeds between which the motor will accelerate at the slow rate to provide a 'distribution period'. The relationships are

$$V_{rb} = 2V_6 \qquad \ldots 9$$

$$\text{For } V_6 \leqslant 1.2\text{V}, V_{ra} = V_6 \qquad \ldots 10$$

$$\text{For } V_6 \geqslant 1.2\text{V}, V_{ra} = 1.2\text{V} \qquad \ldots 11$$

During the distribution period the ramp rate is predominantly defined by the current provided by R_{20}. The average slow ramp rate (V_{rs}) may be calculated from

$$V_{rs} \triangleq \frac{2V_{cc} - 2V_{be} - V_{ra} - V_{rb}}{2R_{20}C_{10}} \times 10^3 \text{ mV/s} \quad \ldots 12$$

Simplifying gives

$$V_{rs} \triangleq \frac{30 - V_{ra} - V_{rb}}{2R_{20}C_{10}} \times 10^3 \text{ mV/s} \qquad \ldots 13$$

The above expressions do not take account of the capacitor leakage current nor the residual charging current from pin 7. These parameters work against one another and therefore are self compensating to some extent. The leakage current of C_{10} should be specified at a voltage equal to $V_{rb} + V_{be}$.

The distribution period (T_d) may be calculated from

$$T_d = \frac{V_{ra} - V_{rb}}{V_{rs}} \times 10^{-3} \text{ s} \qquad \ldots 14$$

If a distribution period is not required, then pin 6 should be connected to common (pin 8). This circuit will then maintain a fast ramp up to the programmed speed voltage. A continuous slow ramp of exponential character can be provided by connecting pin 6 to pin 7. This maintains the circuit in a 'distribution' condition where the ramp is defined by R_{20} and C_{10}. Note that the bias current for pin 6 should be taken into account; it is expected to be less than -10μA under these conditions.

SPEED PROGRAM VOLTAGE

The speed program voltage (V_5) on pin 5 must exceed the low threshold level of 80 mV. Timing functions will be reset and triac drive pulses will be inhibited if pin 5 is programmed below this level. The working range of V_5 is hence 80mV to 13.5 volts.

Pin 5 may be programmed by switching a resistor network to supply the required voltage levels. A small capacitor (C_{12}) may be required to prevent the ramp generator being reset due to pin 5 input going momentarily low.

THE CONTROL AMPLIFIER

The differential control amplifier is normally used to compare the analogue feedback voltage (V_f), pin 4, with the internal speed reference voltage (V_s) and hence derive a phase control voltage (V_p) on pin 16. The amplifier has a transconductance gain of 300μA/V with a limited bidirectional output drive capability of ±100μA. Hence proportional control occurs for a differential error input of ±330mV.

The gain and phase compensation for closed loop control systems are determined by R_{13}, C_8 and C_9 connected to pin 16. These components are best chosen empirically to achieve a best compromise in terms of speed overshoot and response time.

For manual or open loop phase control, the control amplifier may be used as a buffer amplifier and use made of the ramp generator to control the rate of phase angle increase. This may be accomplished by connecting pin 4 to pin 16, grounding pin 12 to pin 8 and controlling the phase angle via the voltage applied to pin 5.

The maximum phase angle may be limited in both open and closed loop control systems by clamping the maximum voltage on pin 16 by means of a zener diode or other clamping device. Since there is only 100μA current drive from the control amplifier, it is important that the clamping device or circuit has a sharp turn-on knee.

During a reset condition pin 16 will be pulled low, ensuring that no output pulses are generated. When the inhibit signal is removed the phase angle increases from zero conduction at a controlled rate.

ZERO VOLTAGE DETECTOR

The sole purpose of the zero voltage detector is to reset the ramp generator of the pulse timing circuit at the zero voltage point of the mains cycle.

The AC mains is applied, via R_4, to a synchronisation circuit (pin 2) which produces a reset pulse whenever the input current is between ±50μA. The pulse is symmetrical around the zero voltage points, which ensures that positive and negative wave triac conduction symmetry can be obtained.

R_4 should be chosen to limit the peak current drive to pin 2 to be slightly less than ±1mA.

LOAD CURRENT DETECTOR

The load current detector inhibits triac gate pulses being generated by the pulse timing circuit until correct conditions exist for the triac to latch when fired. This condition exists when there is sufficient voltage across the triac to induce the required latching current within the duration of a firing pulse.

The triac voltage is monitored by means of R_5 in a similar manner to the zero voltage detector. In this case triac gate pulses are inhibited if the current into pin 1 is not greater than ±50μA. Again the peak current drive should not exceed ±1mA. From the above it follows that the minimum voltage across the triac when a gate pulse is supplied is given by

$$V_{tx} = R_5 \times 50 \times 10^{-6} \text{ volts} \qquad \ldots 15$$

TRIAC PULSE TIMING

The function of the pulse timing circuit is to control the delay and duration of the triac firing pulse. The pulse position is determined by resetting the ramp generator at the mains zero voltage points and triggering the pulse generating circuit when the ramp reaches a level determined by the phase angle control voltage on pin 16. With inductive loads the pulse may be further delayed by the load current detector circuit.

Full power may be supplied to inductive loads since when maximum conduction is demanded the triac pulse is delayed until the lagging load current from the previous half cycle has reduced to zero. At this point the triac will cease to conduct and the supply voltage will appear across it, which when detected initiates the next triac pulse.

At high motor speeds brush bounce may become severe and cause interruptions of the motor load current. Under these conditions the load current detector will respond to the supply voltage appearing across the triac and hence enable a retriggering pulse to be supplied.

The ramp waveform is generated by charging capacitor C_7 up to 12.8volts (nominal) during the zero voltage pulse determined by the zero voltage detector (pin 2). The charging current in this period is limited by an internal impedance of approximately 500ohms. After the zero voltage pulse, C_7 is discharged in a linear fashion by a current sink (I_d), defined externally on pin 15. When the voltage on C_7 reaches a value determined by the phase control voltage on pin 16 a triac gate pulse is initiated. The dynamic working range of this ramp generator is 11.7volts, i.e. the triac gate pulse may be created at any time before the ramp waveform has decreased by this voltage.

The triac pulse duration is determined by recharging C_7 with an internally defined current (I_r) to a voltage 100mV (nominal) above the original trip voltage. During this period the discharge current (I_d) is maintained and hence works against the charging current (I_r). Therefore, I_d must be smaller than I_r for the circuit to function as a pulse generator.

If retriggering occurs, the minimum delay will be determined by the time taken for the current I_d to discharge C_7 back to the original trip voltage i.e. back through 100mV. The maximum retriggering rate (t_r) is thus determined by this delay time plus the pulse duration.

Triac Pulse Timing Equations

Ramp discharge current

$$I_d = \frac{(V_{cc} - V_{be})}{R_{21}} \times 10^6 \ \mu A \qquad \ldots 16$$

Dynamic ramp voltage on pin 14

$$V_{rp} = \frac{I_d \times 10^{-6}}{2 \times f_m \times C_7} \text{ Volts} \qquad \ldots 17$$

Limitation on V_{rp} for full phase control

$$V_{rp} < 11.7 \text{Volts} \qquad \ldots 18$$

TRIAC GATE PULSE

A triac pulse width of 50μs is suitable for most general purpose triacs. Standard component values for C_7 and R_{21} may hence be used which are as follows:

For 50Hz supply

C_7 = 47nF ±10%
R_{21} = 300kΩ ±5%

For 60Hz supply

C_7 = 47nF ±10%
R_{21} = 270kΩ ±5%

With the above components the retriggering period will be approximately 200μs

TRIAC GATE DRIVE

The triac gate pulse is amplified by a buffer amplifier that provides a positive low impedance emitter follower output drive to pin 13.

The current drive required will depend on the characteristics of the triac used. It is important to provide sufficient gate current to guarantee complete bulk conduction is achieved; if not, hot spots may occur which will reduce the life of the triac. The worst case condition is likely to exist when the device is fired in the fourth quadrant (i.e. positive current drive into the gate when a negative voltage is present on Main Terminal 2 (MT2) of the triac).

With sensitive triacs, R_7 may be required to provide a path for the output leakage current and make the triac less susceptible to false triggering from electrical noise.

The triac gate current drive may be calculated from

$$I_{tg} = \frac{V_{13} - V_{tg}}{R_6} - \frac{V_{tg}}{R_7} \times 10^3 \text{ mA} \qquad \ldots 19$$

TRIAC LATCHING

As mentioned before, it is necessary to trigger the triac when conditions are right for a latching current to be established within the period of the gate pulse.

When switching on an inductive load the initial current will increase from zero at a rate dependent on the voltage across and the inductance of the load (the minimum voltage being determined by the load current detector). To help with latching, additional triac load current for a short duration can be provided if required by means of a series RC network in parallel with the triac. C_1 and R_{10} provide this function as well as offering some protection from dv/dt triggering of the triac due to noise spikes on the mains.

OVERLOAD CURRENT PROTECTION

The purpose of motor current limitation is more to protect the triac than the motor itself. Since the stall current is generally much higher than that required for maximum working torque, a limitation can be set at a lower value thus guaranteeing safe operation of the triac under all load conditions.

Peak load current limiting can be provided by discharging the ramp generator capacitor (pin 7) with a current that is proportional to the current drawn from pin 3, when the trip threshold is exceeded. This reduces the internal speed reference voltage (V_s) to a level such that a reduction in phase angle conduction is made, hence reducing the load current. The current limit input is a common base transistor which conducts when the emitter, connected to pin 3, is driven negatively with respect to common (pin 8). The current gain (A_{II}) is the ratio of the discharge current from pin 7 to the current drawn from pin 3.

Load current is monitored by means of a low value resistor (R_{11}) connected in series with the load. The voltage developed across this resistor drives the current limit circuit via resistors R_3 and R_8, such that the voltage on pin 3 is zero at the desired peak load current. The sensitivity of the circuit (i.e. the rate at which the circuit reacts to over-current) will depend on the drive impedance, this being predominantly determined by the resistance of R_8. With a circuit as shown in the reference circuit diagram the load current is monitored in the negative supply cycle.

The value of R_{11} is normally chosen such that a fraction of a volt is generated across it, thus minimising power dissipation yet providing a reasonable signal to drive the overload current circuit. The peak load current is determined by

$$I_{pl} = \frac{V_{cc}}{R_{11}} \times \frac{R_8}{R_3} \text{ A} \qquad \ldots 20$$

High frequency noise may be generated by short duration changes in load current produced by commutator action in a motor load. Due to the low impedance required R_{11} will normally be a wire wound resistor and hence have some inductance, which will increase the noise voltage driving into pin 3. This can be filtered by the inclusion of capacitor C_4.

If overload current limiting is not required, pin 3 should be left open circuit.

CURRENT CONSUMPTION

The total supply current required can be calculated from the sum of the following:

I IC operating current

This is the current required by the circuit which is not dependent on external circuitry.

$$i_I = 7.4\text{mA} \pm 20\% \qquad \ldots 21$$

II Slow ramp generator current

This is usually very small and may be neglected. If required it may be calculated from:-

$$i_{II} = \frac{V_{CC}}{R_{20}} \times 10^3 \text{ mA} \qquad \ldots 22$$

III Frequency to analogue conversion current

This is the additional dynamic operating current required. Again this is usually negligible but may be calculated from:-

$$i_{III} = f_t (V_{cc} - 2V_{be}) C_{11} (1 + A_t) \times 10^3 \text{ mA} \qquad \ldots 23$$

IV Voltage and current synchronisation currents

The AC input currents to pins 1 & 2 cause a drain from the positive sypply, the additional current required is given by:-

$$i_{IV} = \frac{\sqrt{2}\, V_{AC}}{\pi} \left(\frac{1}{R_4} + \frac{1}{R_5} \right) 10^3 \text{ mA} \qquad \ldots 24$$

V Pulse timing current

This is the dynamic operating current of the pulse timing circuit which is determined by the current fed into pin 15. Normally this current is small and has little effect on the total current required.

$$i_V = \frac{2(V_{cc} - V_{be})}{R_{21}} \times 10^3 \text{ mA} \qquad \ldots 25$$

VI Triac gate current

The average triac gate drive current may be calculated from

$$i_{VI} = 2f_m \times t_p \times I_{tg} (1 + P_t) \times 10^{-6} \text{ mA} \qquad \ldots 26$$

The probability factor P_t has been incorporated to take account of current required for additional triac pulses. These will only be required if the load current is interrupted, for example by motor brush bounce.

VII Other external circuitry

Regulated supply current may also be required for biasing control inputs to pins 5 and 7 and other auxilliary circuitry.

When a reset condition exists the IC operating current increases by a maximum of 1 mA. This will occur when the supply is being established hence this current needs to be catered for. However during a reset condition no triac pulses will be generated, therefore only the greater of these two currents needs to be provided.

When calculating the supply current required, the worst case conditions (i.e. component tolerance etc) should be incorporated in the above equations.

$$I_s = \Sigma i \qquad ...27$$

VOLTAGE REGULATOR CIRCUIT

A shunt type voltage regulator circuit is incorporated in the circuit to maintain a steady positive supply on pin 9. Ths enables the device to be driven direct from the mains via current limiting and smoothing components. Since the current shunt (pin 10) is not directly connected to the positive supply (pin 9) it is also possible to power the circuit direct from a DC supply or use pin 10 to drive a series regulating transistor as shown in Fig.7.

A voltage monitor circuit senses the voltage on pin 9 (V_{cc}), this inhibits triac firing pulses and resets the timing functions until an adequate supply for correct circuit operation has been established. Hysteresis in the monitor circuit gives rise to two trip levels, namely the enable (V_{me}) and disable (V_{md}) voltages.

Where use is made of the shunt regulator, unwanted current is drained by pin 10 to common. Power dissipation by the device can be minimised by incorporating resistor R_{22}, enabling greater supply currents to be regulated. Under worst case conditions it is important that the voltage dropped across this resistor does not exceed 13volts.

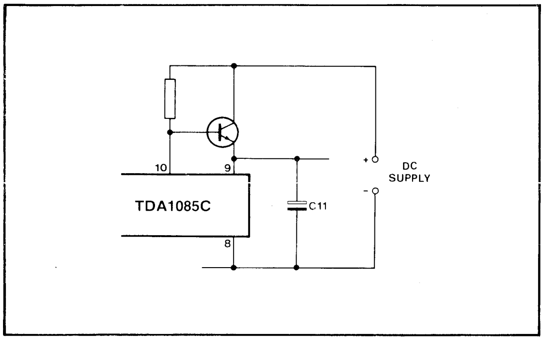


Fig.7 Series regulated DC supply

AC SUPPLY CIRCUITS

The simplest AC supply circuit is shown in Fig.8. This circuit will produce ripple on the regulated supply (pin 9) and will hence cause some asymmetry in firing between positive and negative cycles of the mains. Component values may be calculated from:

$$C_{11} = \frac{I_s}{V_{cr} \times f_m} \times 10^3\,\mu F \qquad ...28$$

$$R_1 = \frac{\frac{\sqrt{2}}{\pi} V_{ac} - V_{cc}}{I_s\,(mA)} \times 10^3 \text{ ohms} \qquad ...29$$

$$P_{dr} = \frac{(\sqrt{2}\,V_{ac} - V_{cc})^2}{4R_1} \text{ Watts} \qquad ...30$$

Where it is important to provide symmetrical firing, further filtering of the AC supply will be required as shown in Fig. 9. Although additional components are required the total capacitance is less than that required in the simple circuit.

The circuit should be designed such that the half wave rectified current is roughly smoothed by capacitor C_2. R_2 and C_2 are chosen such that they are capable of maintaining the average current required by the circuit (I_s).

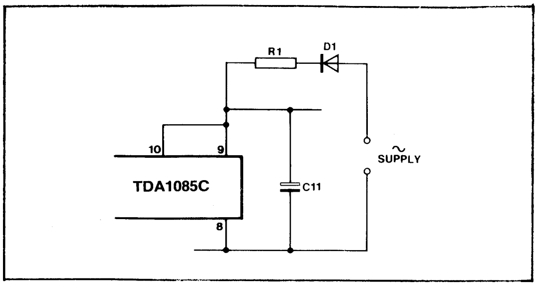


Fig.8 Simple shunt regulated supply

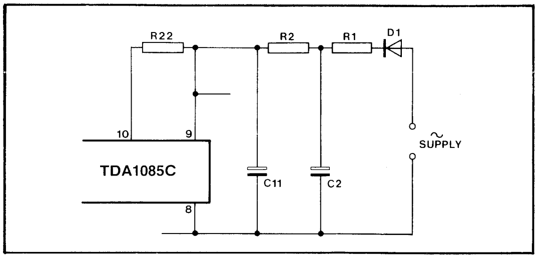


Fig.9 Resistive feed shunt regulated to provide a low ripple supply

The peak demands during triac gate pulses are then catered for by capacitor C_{11}. The dropper resistors may be calculated from:

$$R_1 + R_2 = \frac{\frac{\sqrt{2}}{\pi} V_{ac} - V_{cc}}{I_s(mA)} \times 10^3 \text{ ohms} \qquad ...31$$

$$P_{dr} = \frac{(\sqrt{2}V_{ac} - V_{cc} - I_sR_2)^2}{4R_1} \text{Watts} \qquad ...32$$

Where power dissipation is a problem the circuit may be powered by a reactive feed from the AC supply as shown in Fig. 8. Resistor R_x should be included to limit current due to noise spikes from the supply. An impedance of the order of 200ohms is suitable for this purpose. Neglecting the effects of this resistor, the value of capacitor C_x may be calculated from:-

$$C_x = \frac{I_s}{f_m\,(2\sqrt{2}V_{ac} - I_sR_2 - V_{cc})} \times 10^3 \mu F \qquad ...33$$

NB *Worst case conditions should be put in the above equations when calculating component values etc.*

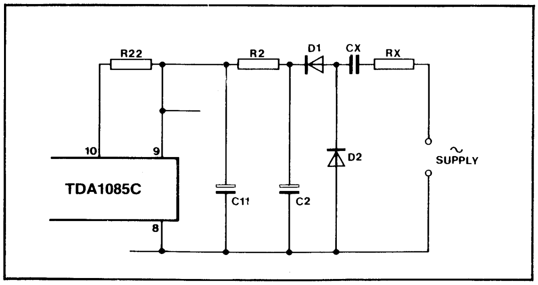


Fig.10 Reactive feed shunt regulated to provide a low ripple supply with minimum power dissipation

TRIAC LATCHING CIRCUIT

When driving inductive loads a series RC network may be required across the triac. This is to provide a short duration load current in the triac while the current in the main inductive load is being established after a gate pulse is applied. In this way a latching current can be quickly established, even when the triac is fired at low voltage points in the mains cycle. C_1 and R_{10} provide this function as shown in Fig.6.

SYMBOLS USED IN TEXT

Symbol	Function	Units
A_{il}	Current limit gain	—
A_t	IC tacho conversion gain	—
f_m	Mains frequency	Hz
f_f	Tacho frequency	Hz
I_d	Pulse ramp discharge current	μA
I_r	Pulse ramp recharge current	μA
I_{rf}	Fast ramp current	mA
I_s	Supply current	mA
I_{fg}	Peak triac gate current	mA
K	Tacho conversion factor	mV/Hz
N	Number of tacho poles	—
P_{dr}	Power dissipation by dropper resistor (R1)	Watts
P_t	Probability of extra triac pulse	—
S	Motor speed	RPM
t_d	Distribution period	seconds
t_p	Pulse duration	μs
t_r	Pulse retriggering rate	μs
V_{ac}	AC supply voltage (RMS)	volts
V_{be}	Transistor emitter base voltage	volts
V_{cc}	Positive rail voltage (pin 9)	volts
V_{cr}	Supply ripple voltage	volts
V_f	Analog feedback voltage	volts
V_{fr}	Feedback voltage ripple (pk—pk)	mV
V_{me}	Voltage monitor enable level	volts
V_{md}	Voltage monitor disable level	volts
V_p	Phase control voltage	volts
V_{ra}	Ramp voltage at first knee	volts
V_{rb}	Ramp voltage at second knee	volts
V_{rf}	Fast ramp rate	mV/s
V_{rp}	Dynamic ramp voltage	volts
V_{rs}	Slow ramp rate	mV/s
V_s	Internal speed reference voltage	volts
V_{tg}	Triac gate voltage	volts
V_{fo}	Tacho offset voltage	mV
V_{fx}	Voltage across triac	volts
V_5	Speed program voltage on pin 5	volts
V_6	Distribution level programmed on pin 6	volts
V_{13}	Pulse drive voltage from pin 13	volts

Motor Control Applications

THE UNIVERSAL MOTOR

This is a machine which has a commutator drive to the armature and a field that is polarised by the supply. The field and armature may be series or parallel connected such that the machine in principle could be driven from a DC or AC supply. Most domestic type motors are series connected.

In controlling this type of machine, the phase angle may be varied from zero to a maximum determined by the lag in load current due to inductance. To obtain full power it is therefore necessary to have a load current detection circuit such that the triac is not fired before the current from the previous half cycle has reduced to zero.

At high motor speeds brush bounce may also be a problem. This can cause an interruption in load current and hence unlatch the triac, reducing the power to the motor. To overcome this problem it is necessary to detect the situation and retrigger the triac.

Both these problems are overcome in the TDA1085C circuit by means of the load current synchronisation circuit (pin 1).

THE FIXED FIELD MOTOR

This is a machine which has a constant field which may be provided by permanent magnets in the stator. The armature requires a DC supply to drive the motor, and hence this may be said to be a DC machine.

This type of motor may be driven from an AC supply by means of a rectifying circuit. The machine will generate a back EMF that is proportional to its speed and will therefore only draw load current when the supply voltage is greater than the generated EMF.

When driving this type of load with a phase control circuit the triac cannot be latched before a 90° phase angle since the EMF generated will be almost equal to the peak supply voltage from previous cycles, and hence no load current will flow until the peak supply voltage is reached again. For this reason it is desirable to be able to limit the triac gate pulse to the second half of each half cycle of the supply. With the TDA1085C the maximum conduction angle may be limited by restricting the voltage on pin 16 by means of a zener diode.

Since load current only follows for a short period of each half cycle a high peak current is to be expected. This, if unchecked, may cause damage to the triac and rectifying devices. By incorporating an inductor in series with the motor, the load current may be controlled in its build-up rate and spread over a greater period, hence reducing its peak value for a particular load demand.

THE INDUCTION MOTOR

The principle of an induction motor is to generate a rotating magnetic field in which the rotor is placed. Due to the generation of eddy currents the rotor will react and follow the field. The difference between the field and rotor speeds is known as the slip speed which increases with applied load.

The main disadvantage of this type of machine is that it has a poor torque speed characteristic which makes it unsuitable for variable speed applications where a high torque is required at low speeds. They may however, be suitable for driving loads such as fans or centrifugal pumps where the load torque reduces with decreasing speed.

Due to the high inductance of this type of machine a poor load power factor results. This may be improved by running the motor at a fixed slip speed by the use of a phase control circuit. A significant saving in real power consumed will also be obtained when the motor is lightly loaded.

When using phase control with this type of motor it is most important that symmetrical firing of the positive and negative waves is achieved otherwise a small net DC voltage may generate a high DC current in the stator windings. The TDA1085A is capable of meeting this requirement.

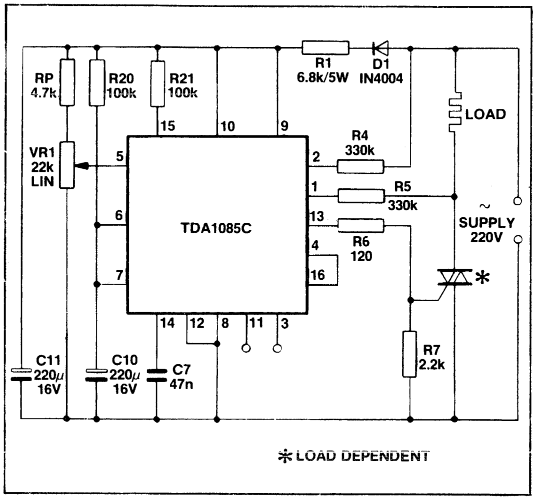


Fig.11 Manual phase control circuit

MANUAL PHASE CONTROL CIRCUIT

Fig.11 shows an open loop phase control circuit using the ramp generator of the TDA1085C to limit the rate of increase of the phase angle. R_{20} and C_{10} give a time constant of 22 seconds.

UNIVERSAL MOTOR APPLICATION

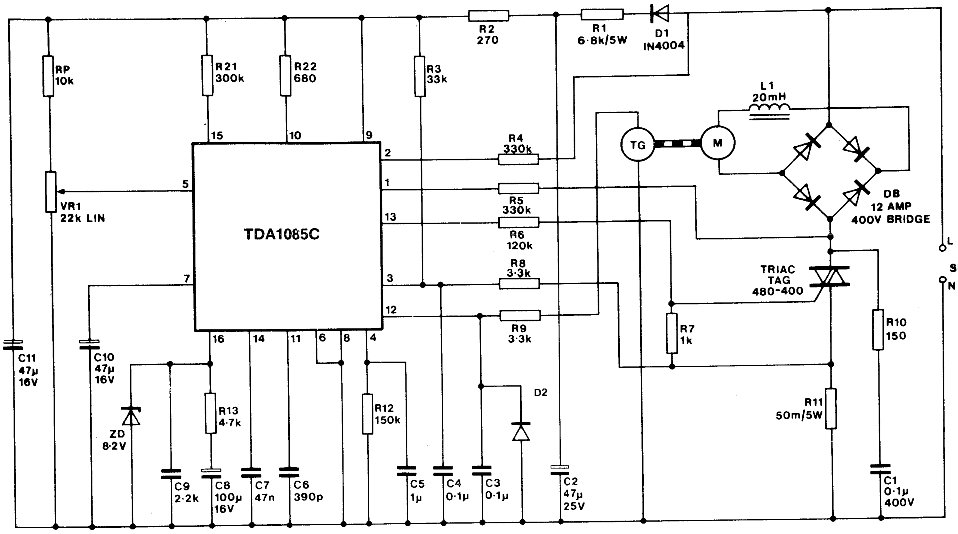
The circuit of Fig. 11 is essentially the same as the reference circuit Fig. 4, but with component values added. The specification is as follows:

Supply: 220V ± 15% 58Hz
Motor: Normal load current 7A RMS
Peak load current limit 21A
Tacho: 8 poles
Amplitude at max. speed 14V RMS
Motor speed requirements Wash speed 800RPM
Distribute speeds 600 to 1200RPM
Spin speeds 5,000RPM
Super spin speeds 10,000RPM
Distribution time: 20 seconds

FIXED FIELD MOTOR APPLICATION CIRCUIT

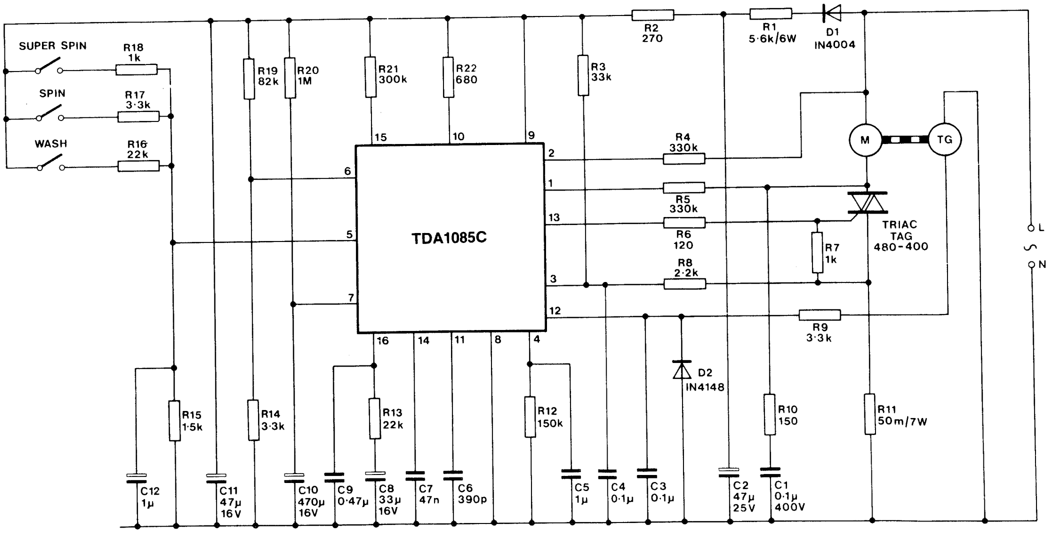
Specification for the circuit shown in Fig. 10:

Supply: 220V ± 15% 50Hz
Motor: Peak load current limit 30A
Tacho: 8 poles
Amplitude at maximum speed 14V RMS
Motor speed: Variable up to 10,000 RPM



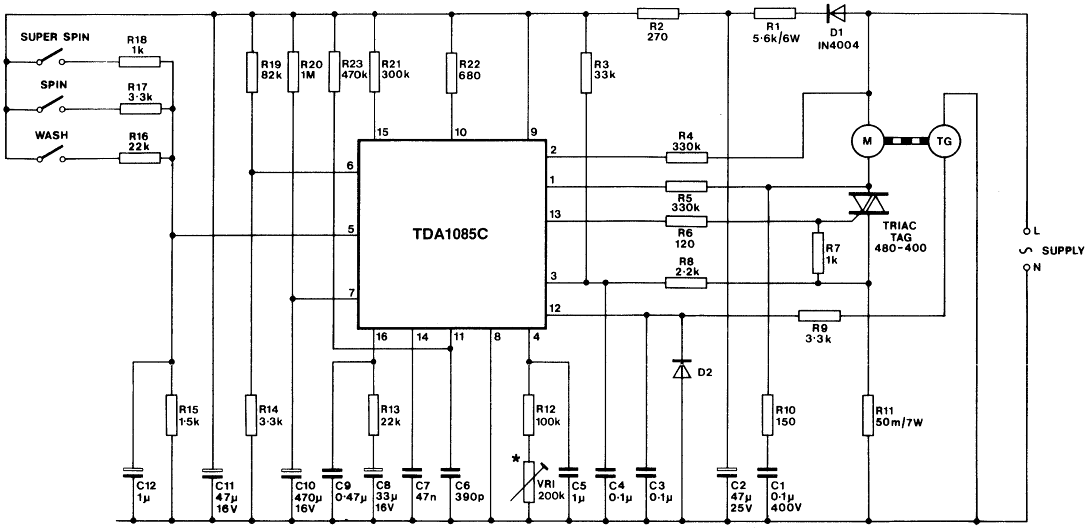
***DIODE NOT REQUIRED IF TACHO VOLTAGE AT PIN 12 IS LESS THAN 6V P-P**

Fig.12 Fixed field motor application circuit



***DIODE NOT REQUIRED IF TACHO VOLTAGE AT PIN 12 IS LESS THAN 6V P-P**

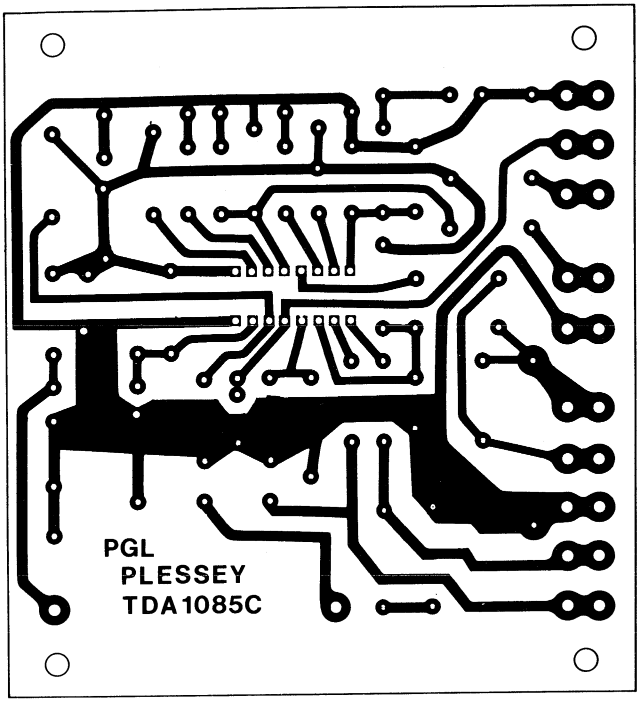
Fig. 13a Universal motor application circuit



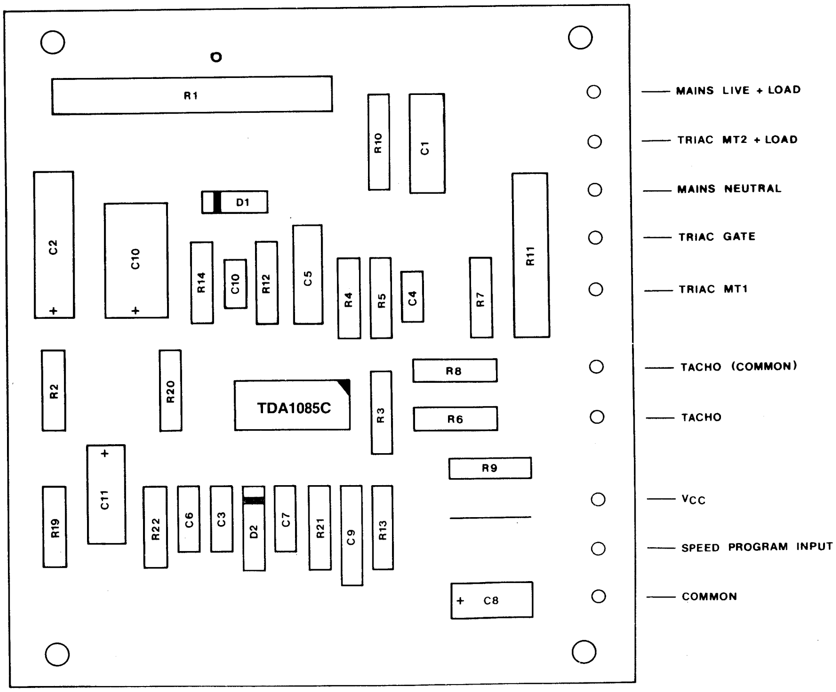
***DIODE NOT REQUIRED IF TACHO VOLTAGE AT PIN 12 IS LESS THAN 6V P-P**

† Adjust for the highest speed.

Fig.13b Calibrated universal motor application circuit



(a) Copper side



(b) Component layout

***DIODE NOT REQUIRED IF TACHO VOLTAGE AT PIN 12 IS LESS THAN 6V P-P**

Fig.14 PCB for motor speed control applications

PLESSEY
Semiconductors

TDA2085A

PHASE CONTROL INTEGRATED CIRCUIT

The TDA2085A is a silicon integrated circuit designed for use in closed or open loop phase control circuits of AC with resistive or inductive loads. In closed loop systems analogue voltage or tacho frequency feedback may be used.

The circuit was primarily designed for motor speed control in power drills, foodmixers, washing machines etc.

In the event of an open circuit tacho generator connection the TDA2085A will demand full speed/power.

FEATURES

- Powered Direct from AC Mains or DC Line
- −5V Supply Available for Ancillary Circuitry
- Low Supply Current Consumption
- Average or Peak Load Current Limiting
- Ramp Generator to Provide Controlled Acceleration
- Negative Triac Firing Pulses
- Warning LED Drive Circuit
- Actual Speed Derived from Tachogenerator Frequency or Analogue Feedback
- Well Defined Control Voltage/Phase Angle Relationship
- Inhibit Input for use with Thermistor Temperature Sensors

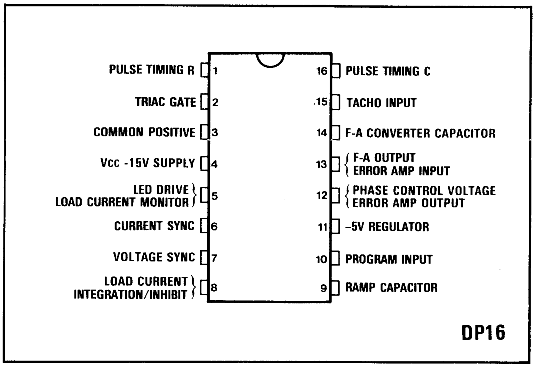


Fig.1 Pin connections - top view

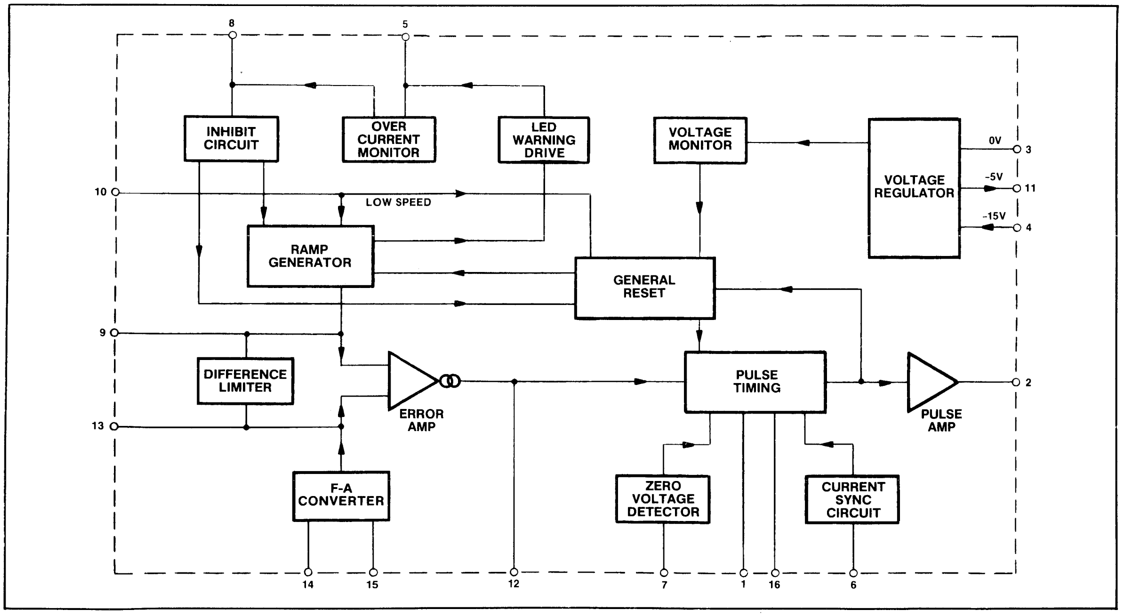


Fig.1A Block diagram of TDA2085A

SPECIAL FEATURES

Low Supply Current Consumption

Due to the low current consumption of the device the power dissipation in the mains dropper resistor may be as low as one watt on a 220V AC supply (0.5W on 110V).

By incorporating both a shunt and a series voltage regulator in the IC design, a high ripple voltage can be accommodated on the supply smoothing capacitor.

The combination of the above two features result in reduced size and a minimum count of components used in the power supply circuitry.

Powered Direct from AC Mains or DC Line

This device incorporates a shunt regulator (-15V) such that it may be powered from an AC or DC supply via current limiting components or the device may be powered direct from a -12V DC supply.

—5V Supply Available for Ancillary Circuitry

A -5V series regulator is incorporated to provide a smooth supply for the internal analogue control functions. This supply may be used externally to power ancillary circuitry such as timing circuits and other logic control circuits etc, as well as driving potentiometers for the analogue control inputs.

Due to this supply technique, greater symmetry between positive and negative half cycle firing phase angle will result.

Low Supply Inhibit Circuit

Timing functions and triac gate drive pulses are inhibited until there is sufficient supply voltage across the device to guarantee complete gate drive pulses.

This ensures that bulk conduction is established in the triac and correct linear operation of the control system is maintained.

Negative Triac Gate Firing Pulses

Since the device works with the positive supply as common, the triac gate pulses are negative going. This is an advantage when selecting a suitable triac since most triac manufacturers prefer this drive polarity.

The device is designed to give a triac pulse that is greater than 50mA for a period of 50 microseconds with standard pulse timing components (47nF, pin 16). Repeated triac gate pulses are given if the triac fails to latch or becomes unlatched due to motor brush bounce.

Well-Defined Control Voltage/Phase Angle Relationship

An internal 5V stabiliser circuit is used as the charging voltage for the pulse timing ramp capacitor and as the reference voltage for the speed input potentiometer. This ensures that maximum phase angle can be obtained by adjusting the resistor or capacitor on the pulse timing circuit, without affecting the maximum setting.

Average or Peak Load Current Limiting

The load current is normally sensed in the positive mains cycle by means of a low impedance resistor in series with the triac and load. The voltage drop across this resistor is converted back into a low current source by a second resistor and fed into the load current sensing input (pin 5) of the IC. In high load current applications where the power dissipated in a series sensing resistor would be unacceptable, a current transformer may be utilised.

The current fed into the sensing input (pin 5) is mirrored by the IC and fed to the inhibit input (pin 8). Peak current limiting can be provided at this point by inserting a resistor between pin 8 and common (pin 3), whereas average current limiting requires the addition of an integrating capacitor.

When average current limiting is used the double action of the inhibit circuit is utilised. This has two trip points such that when the first trip point (-1V) is reached the power to the load will be gradually reduced by decreasing the voltage on the ramp capacitor, (the discharge rate being equal but opposite to the soft start), hence reducing the power and providing a constant current drive (producing constant torque) to the motor. When the second trip point (-1.5V) is reached a general reset of all timing functions occurs at a fast rate, hence if a gross overload was suddenly applied to the motor, a rapid reduction in power supplied would result. Since it is not possible to turn the triac off during a cycle, the triac and motor should be chosen to be capable of withstanding one complete mains cycle under the worst overload condition.

Peak load current limiting tends to produce a fold back action (of motor speed and torque) at large conduction phase angle. This is due to the peak current initially increasing when the phase conduction angle is reduced at constant load torque.

Ramp Generator to Provide Controlled Acceleration

The ramp generator is a follower integrator design which can be used to control the acceleration rate up to the programmed speed. This can also be used to control the rate of phase angle increase in open loop control systems.

The ramp rate is defined by an internal current source (25 microamps) and the capacitor connected to pin 9.

Warning LED Drive Circuit

The LED drive circuit is designed to drive an LED in series with the device such that the overall current consumption is minimised by utilising the IC drive current to power the LED. Due to the multiplexing technique on pin 5, some additional current will be required when the circuit is used to provide both load current limit and LED drive (this will normally be about 0.5 microamps).

The LED will illuminate under one of the following two conditions:

1. The programme speed (or phase in open loop systems) is set for zero.
2. The running speed is less than that programmed.

Hence, indication will be given when the system is powered up but zero power demanded, or when the machine cannot maintain the set operating speed due to the load current circuit operating. The LED will also be illuminated while the soft start function is in operation i.e., the LED will turn off only when the set speed has been reached.

Actual Speed Derived from Tacho Generator Frequency or Analogue Feedback

Tacho frequency or analogue feedback may be used with this device. When frequency feedback is used, the frequency to analogue (F-A) conversion circuit is used. This circuit is extremely linear and tracks the regulated (-5V) supply.

Frequency feedback has the advantage of not being dependent on mechanical clearance, magnetic strength, etc., and since the conversion rate is defined by two external components, accurate speed programming can be obtained without the need for calibration.

CIRCUIT DESCRIPTION (Figs. 1A and 2)

The TDA2085 incorporates a shunt stabiliser which enables it to be powered direct from the mains via current limiting components or from a DC supply. In addition an on chip series regulator provides a -5V supply which powers various internal circuits, the speed programming potentiometer and other ancillary components. Up to 5mA is available from this supply for powering additional external circuitry. A supply voltage monitor circuit prevents triac firing pulses from being generated until an adequate supply voltage is established and by discharging the ramp capacitor, ensures a soft start when the supply returns to normal after a short interruption.

Motor acceleration is controlled by a ramp generator to a maximum determined by the speed program input. Grounding the speed program input will cause a general reset and inhibit the triac firing pulses. The ramp generator rise time and therefore the motor acceleration is determined by a fixed internal charging current and an external capacitor.

For use in closed loop systems, a frequency to analogue (F-A) converter provides a DC voltage proportional to motor speed, sensed at the tacho input. The conversion is made by transferring a pulse of charge from the F-A converter capacitor to an RC filter on the F-A output pin. Hysteresis on the tacho input prevents noise from giving a false indication of motor speed.

The error amplifier has differential inputs that compare the ramp generator voltage with the actual speed voltage from the F-A converter. A clamp circuit across the amplifier inputs prevents the differential input voltages exceeding about ±0.5V. The output from this amplifier is a bidirectional current of limited amplitude which is integrated to limit the maximum rate of change of triac firing pulse angle. For use in open loop systems the amplifier is connected as a voltage follower and acts as a buffer between the ramp generator and pulse timing circuit.

Triac firing pulse synchronisation is achieved by delaying the pulse with reference to the zero crossing voltage points of the mains cycle as determined by the zero voltage detection circuit. With inductive loads, the load current will phase lag the mains voltage, and under these conditions the triac firing pulse must be delayed until the load current from the previous half cycle has ceased. The current synchronisation circuit satisfies this requirement by preventing firing pulses until a voltage drop appears across the triac. If the triac fails to latch repeated firing pulses will be supplied. The firing pulse width and the spacing of repeated pulses are controlled by a single capacitor.

An average load current limit circuit, which works on positive mains half cycles only, is used to protect the triac and motor under stall conditions. External resistors determine the trip point which operates at two levels: the first under moderate overload conditions discharges the soft start capacitor with a constant current until a safe load current is reached, whilst the second initiates a general reset and rapid discharge of the soft start capacitor.

A warning LED may be connected in series with the -15V supply to give an indication that motor speed has not reached the programmed value or that zero speed is demanded. The LED is extinguished by shunting the supply current to -15V during negative mains half cycles by internal circuitry on the load current monitor pin.

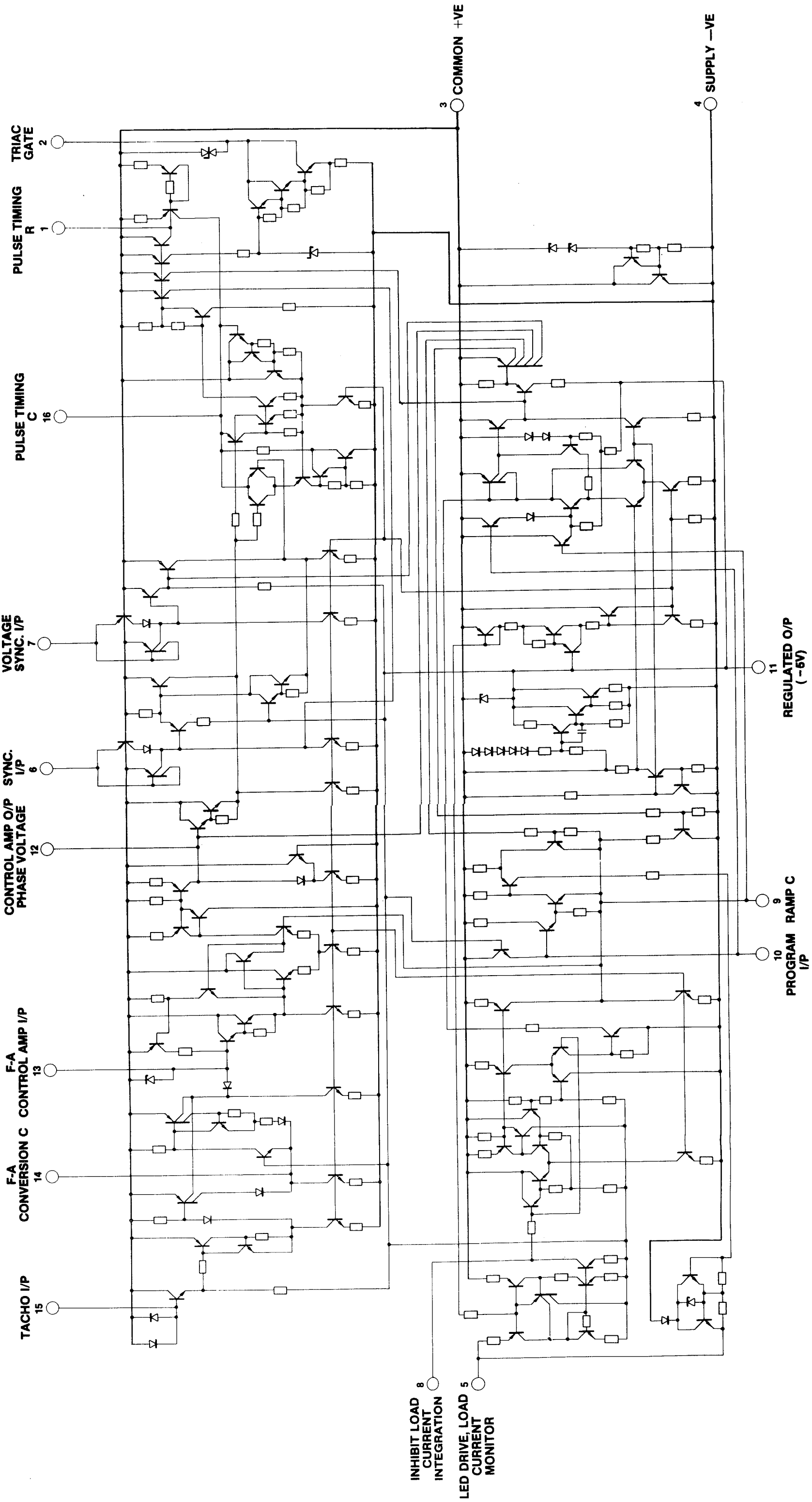


Fig.2 TDA2085A circuit diagram

ELECTRICAL CHARACTERISTICS

Test conditions (unless otherwise stated):

T_{amb} = +25°C

All potentials measured with respect to common (Pin 3) (unless otherwise stated)

Characteristic	Value			Units	Conditions
	Min.	Typ.	Max.		
CURRENT CONSUMPTION					
Pin 4					
IC Operating current		2.8	3.8	mA	Pin 4 voltage = 13.0V including triac gate drive current
SHUNT VOLTAGE REGULATOR					
Pin 4					
Regulating voltage	-15	-14	-13	V	Full temperature range
Voltage monitor enable level	-11		-9	V	
SERIES REGULATOR					
Pin 11					
Regulating voltage (Vreg)	-5.35	-5V	-4.65	V	1mA external load
Temperature coefficient			±1	mV/°C	
External load			10	mA	
Regulation	-75		+75	mV	For 0-5mA external load change
RAMP GENERATOR					
Pin 9					
Capacitor charging current	25	30	35	µA	
Capacitor discharge current		25		µA	Load current limit in operation
Capacitor discharge current		10		mA	Load current inhibit in operation 5V on ramp C
Capacitor to actual speed voltage clamp	-0.8		+0.8	V	
SPEED PROGRAM CIRCUIT					
Pin 10					
Input voltage range	Vreg-0.5		0	V	
Input bias current			1	µA	
Zero power demand voltage	-100	-75	-50	mV	
FREQUENCY TO ANALOGUE CONVERTER					
Pin 15					
Tacho input voltage	350			mV	Peak value
Hysteresis	125	175	225	mV	
Bias current			10	µA	
Pin 15 to Pin 14					
Conversion factor (typical application)		0.5		mV/rpm	C pin 14 = 10nF, R pin 13 = 150k, 8 pole tacho 10000 rpm max.
Pin 4 to Pin 13					
Conversion gain		1			
ERROR AMPLIFIER					
Pin 9 and 13					
Input voltage range	Vreg		0	V	
Input bias current			0.5	µA	
Pin 10, 13 and 12					
Input offset voltage	-5		+15	mV	V10-V13 to give $I_6 = 0$
Trans conductance	80	100	120	µA/V	
Pin 12					
Output current drive	±20	±25	±35	µA	

ELECTRICAL CHARACTERISTICS (CONTINUED)

Characteristic	Value Min.	Value Typ.	Value Max.	Units	Conditions
FIRING PULSE TIMING					
Pin 7					
Voltage SYNC trip level	±35	±50	±65	μA	
Pin 6					
Current SYNC trip level	±35	±50	±65	μA	
Pin 16					
Phase control voltage swing	Vreg		0	V	
Pin 13					
Firing pulse width		50		μs	C pin 16 = 47nF
Pulse repetition time		100		μs	C pin 16 = 47nF, R pin 1 = 200k
FIRING PULSE OUTPUT					
Pin 2					
Drive current	50	75	100	mA	Pin 2 V = -3V
Leakage current			10μA		Pin 2 V = 0V
LOAD CURRENT LIMITING					
Pin 5					
Offset voltage			±20	mV	
Pin 5 and 8					
Current gain	0.475	0.5	0.525		Pin 5 current = 100μA
Pin 8					
Voltage for load current limit		-1V			(0.2 Vreg)
Voltage for load current inhibit		-1.5V			(0.3 Vreg)

ABSOLUTE MAXIMUM RATINGS

ELECTRICAL	Value	Units
Triac gate voltage pin 2	4	V
Repetitive peak input current pin 4	80	mA
Non repetitive peak input current pin 4 (tp<250μs)	200	mA
Peak input current pin 5 positive half cycle	2	mA
Repetitive peak input current pin 5 negative half cycle	80	mA
Non repetitive peak input current pin 5 negative half cycle (tp<250μs)	200	mA
Peak input current (ISYNC) pin 6	±3	mA
Peak input current (VSYNC) pin 7	±1	mA
Inhibit input voltage pin 8	Vreg	V
-5V regulator current pin 11	10	mA
Control amp input voltage pin 13	Vreg	V
Tacho input current pin 15	±10	mA
THERMAL		
Operating ambient temperature	0 to +85	°C
Storage temperature	-55 to +125	°C

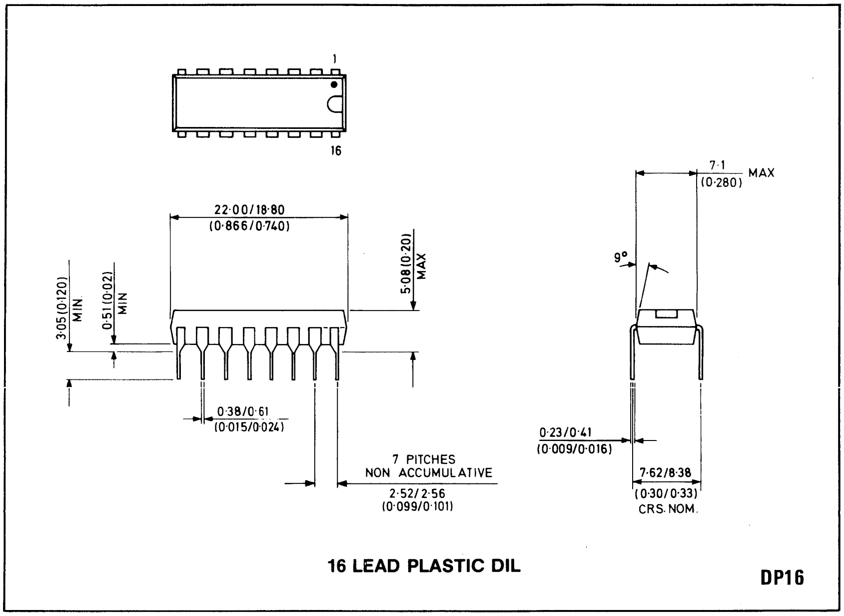
TACHO INPUT DRIVE

The TDA2085A requires less than 10µA (pk) to drive the tacho input (pin 15) and has bidirectional clamping. This makes it possible to connect a tacho pick up coil directly to the device hence minimising component count.

A motor may fail to start up if a signal is picked up by a sensitive tacho due to vibration in the rotor caused by elastic stiction when power is initially applied. This can be easily overcome by incorporating a filtering capacitor across the tacho input.

PACKAGE DETAILS

Dimensions are shown thus: mm (in)



16 LEAD PLASTIC DIL

PLESSEY
Semiconductors

TDA2086

PHASE CONTROL INTEGRATED CIRCUIT

The TDA2086 is a silicon integrated circuit designed for use in closed or open loop phase control circuits of AC with resistive or inductive loads. In closed loop systems analogue voltage or tacho frequency feedback may be used.

The circuit was primarily designed for motor speed control in power drills, foodmixers, washing machines etc.

In the event of an open circuit tacho generator connection the TDA2086 will demand full speed/power.

FEATURES

- Power Direct from AC Mains or DC Line
- 5V Supply Available for Ancillary Circuitry
- Low Supply Current Consumption
- Average or Peak Load Current Limiting
- Ramp Generator to Provide Controlled Acceleration
- Negative Triac Firing Pulses. 100mA Guaranteed Minimum
- Warning LED Drive Circuit
- Actual Speed Derived from Tachogenerator Frequency or Analogue Feedback
- Well Defined Control Voltage/Phase Angle Relationship
- Inhibit Input for use with Thermistor Temperature Sensors

DIFFERENCES BETWEEN TDA2085A AND TDA2086

1. Triac drive current increased to 125mA typical.
2. Tacho hysteresis decreased to 40mV typical.
3. Tacho input current rating increased to ±20mA max.

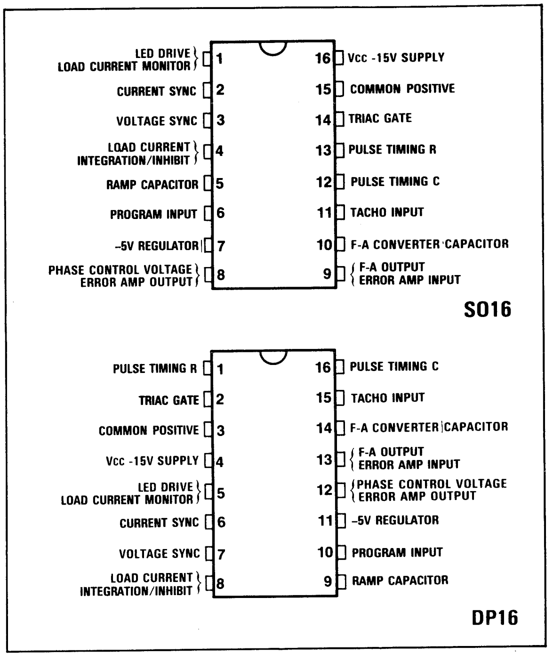


Fig.1 Pin connections - top view

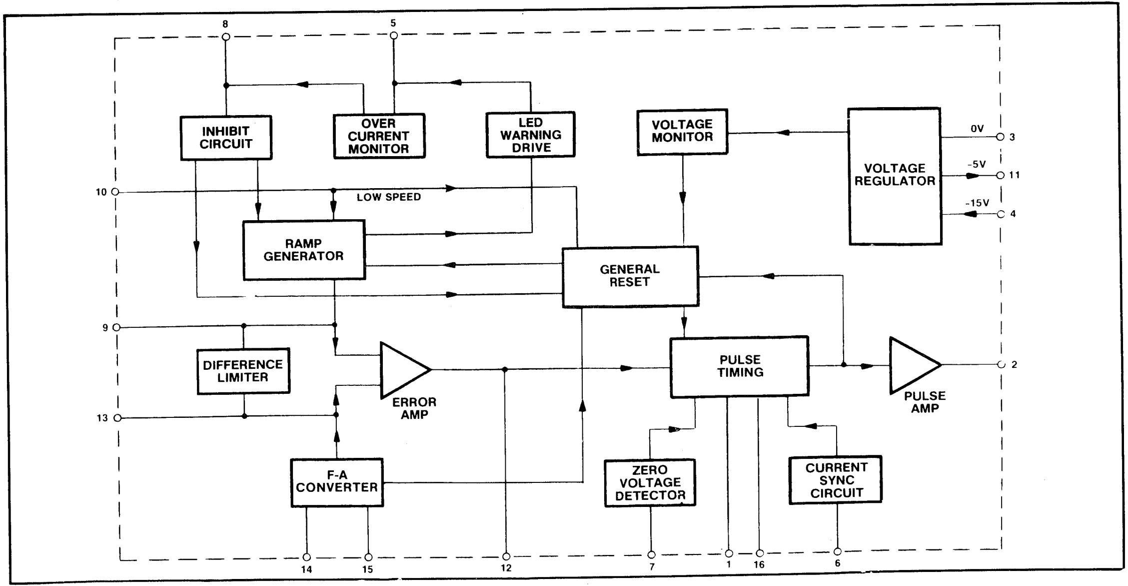


Fig.2 Block diagram of TDA2086

ELECTRICAL CHARACTERISTICS

Tests conditions (unless otherwise stated):

T_{amb} = +25° C
All potentials measured with respect to common (Pin 3) (unless otherwise stated)
Pin numbers refer to DP16 package

Characteristic	Value			Units	Conditions
	Min.	Typ.	Max.		
CURRENT CONSUMPTION					
Pin 4					
IC Operating current		3.1	4.1	mA	Pin 4 voltage = 13.5V including triac gate drive current
SHUNT VOLTAGE REGULATOR					
Pin 4					
Regulating voltage	-16	-14.75	-13.5	V	Full temperature range
Voltage monitor enable level	-11		-9	V	
SERIES REGULATOR					
Pin 11					
Regulating voltage (Vreg)	-5.35	-5	-4.65	V	1mA external load
Temperature coefficient			±1	mV/° C	
External load			10	mA	
Regulation	-75		+75	mV	For 0-5mA external load change
RAMP GENERATOR					
Pin 9					
Capacitor charging current	25	30	35	μA	
Capacitor discharge current		25		μA	Load current limit in operation
Capacitor discharge current		10		mA	Load current inhibit in operation 5V on ramp C
Capacitor to actual speed voltage clamp	-0.8		+0.8	V	
SPEED PROGRAM CIRCUIT					
Pin 10					
Input voltage range	Vreg -0.5		0	V	
Input bias current			1	μA	
Zero power demand voltage	-100	-75	-50	mV	
FREQUENCY TO ANALOGUE CONVERTER					
Pin 15					
Tacho input voltage	100			mV	Peak value
Hysteresis	30	40	60	mV	
Bias current			10	μA	
Pin 15 to Pin 14					
Conversion factor (typical application)		0.5		mV/rpm	C pin 14 = 10nF, R pin 13 = 150k, 8 pole tacho 10000 rpm max.
Pin 4 to Pin 13					
Conversion gain		1			
ERROR AMPLIFIER					
Pin 9 and 13					
Input voltage range	Vreg		0	V	
Input bias current			0.5	μA	
Pin 10, 13 and 12					
Input offset voltage	-5		+15	mV	V10-V13 to give $I_{12} = 0$
Transconductance	80	100	120	μA/V	
Pin 12					
Output current drive	±20		±35	μA	

ELECTRICAL CHARACTERISTICS

Characteristic	Value			Units	Conditions
	Min.	Typ.	Max.		
FIRING PULSE TIMING					
Pin 7					
Voltage SYNC trip level	±35	±50	±65	μA	
Pin 6					
Current SYNC trip level	±35	±50	±65	μA	
Pin 12					
Phase control voltage swing	Vreg		0	V	
Pin 13					
Firing pulse width		50		μs	C pin 16 = 47nF
Pulse repetition time		100		μs	C pin 16 = 47nF, R pin 1 = 200k
FIRING PULSE OUTPUT					
Pin 2					
Drive current	100	125	150	mA	Pin 2 V = -3V
Leakage current			10μA		Pin 2 V = 0V
LOAD CURRENT LIMITING					
Pin 5					
Offset voltage			±20	mV	
Pin 5 and 8					
Current gain	0.475	0.5	0.525		Pin 5 current = 100μA
Pin 8					
Voltage for load current limit		-1V			(0.2 Vreg)
Voltage for load current inhibit		-1.5V			(0.3 Vreg)

ABSOLUTE MAXIMUM RATINGS

ELECTRICAL	Value	Units
Triac gate voltage pin 2	4	V
Repetitive peak input current pin 4	80	mA
Non repetitive peak input current pin 4 (tp 250μs)	200	mA
Peak input current pin 5 positive half cycle	2	mA
Repetitive peak input current pin 5 negative half cycle	80	mA
Non repetitive peak input current pin 5 negative half cycle (tp 250μs)	200	mA
Peak input current (I_{SYNC}) pin 6	±1	mA
Peak input current (V_{SYNC}) pin 7	±1	mA
Inhibit input voltage pin 8	Vreg	V
-5V regulator current pin 11	10	mA
Control amp input voltage pin 13	Vreg	V
Tacho input current pin 15	±20	mA
THERMAL		
Operating ambient temperature	0 to +85	°C
Storage temperature	-55 to +125	°C

TACHO INPUT DRIVE

The TDA2086 requires less than 10μA (pk) to drive the tacho input (pin 15) and has bidirectional clamping. This makes it possible to connect a tacho pick up coil directly to the device hence minimising component count.

A motor may fail to start up if a signal is picked up by a sensitive tacho due to vibration in the rotor caused by elastic sticktion when power is initially applied. This can be easily overcome by incorporating a filtering capacitor across the tacho input.

SPECIAL FEATURES

Low Supply Current Consumption

Due to the low current consumption of the device the power dissipation in the mains dropper resistor may be as low as 1.1W on a 220V AC supply (0.5W on 110V).

By incorporating both a shunt and a series voltage regulator in the IC design, a high ripple voltage can be accommodated on the supply smoothing capacitor.

The combination of the above two features result in reduced size and a minimum count of components used in the power supply circuitry.

Powered Direct from AC Mains or DC Line

This device incorporates a shunt regulator (-15V) such that it may be powered from an AC or DC supply via current limiting components or the device may be powered direct from a -12V DC supply.

-5V Supply available for Ancillary Circuitry

A -5V series regulator is incorporated to provide a smooth supply for the internal analogue control functions. This supply may be used externally to power ancillary circuitry such as timing circuits and other logic control circuits etc, as well as driving potentiometers for the analogue control inputs.

Due to this supply technique, greater symmetry between positive and negative half cycle firing phase angle will result.

Low Supply Inhibit Circuit

Timing functions and triac gate drive pulses are inhibited until there is sufficient supply voltage across the device to guarantee complete gate drive pulses.

This ensures that bulk conduction is established in the triac and correct linear operation of the control system is maintained.

Negative Triac Gate Firing Pulses

Since the device works with the positive supply as common, the triac gate pulses are negative going. This is an advantage when selecting a suitable triac since most triac manufacturers prefer this drive polarity.

The device is designed to give a triac pulse that is greater than 100mA for a period of 50 microseconds with standard pulse timing components (47nF, pin 16). Repeated triac gate pulses are given if the triac fails to latch or becomes unlatched due to motor brush bounce.

Well-Defined Control Voltage/Phase Angle (Open Loop)

An internal 5V stabiliser circuit is used as the charging voltage for the pulse timing ramp capacitor and as the reference voltage for the speed input potentiometer. This ensures that maximum phase angle can be obtained by adjusting the resistor or capacitor on the pulse timing circuit, without affecting the maximum setting.

Average or Peak Load Current Limiting

The load current is normally sensed in the positive mains cycle by means of a low impedance resistor in series with the triac and load. The voltage drop across this resistor is converted back into a low current source by a second resistor and fed into the load current sensing input (pin 5) of the IC. In high load current applications where the power dissipated in a series sensing resistor would be unacceptable, a current transformer may be uitilised.

The current fed into the sensing input (pin 5) is mirrored by the IC and fed to the inhibit input (pin 8). Peak current limiting can be provided at this point by inserting a resistor between pin 8 and common (pin 3), whereas average current limiting requires the addition of an integrating capacitor.

When average current limiting is used the double action of the inhibit circuit is utilised. This has two trip points such that when the first trip point (-1V) is reached the power to the load will be gradually reduced by decreasing the voltage on the ramp capacitor, (the discharge rate being equal but opposite to the soft start), hence reducing the power and providing a constant current drive (producing constant torque) to the motor. When the second trip point (-1.5V) is reached a general reset of all timing functions occurs at a fast rate, hence if a gross overload was suddenly applied to the motor, a rapid reduction in power supplied would result. Since it is not possible to turn the triac off during a cycle, the triac and motor should be chosen to be capable of withstanding one complete mains cycle under the worst overload condition.

Peak load current limiting tends to produce a fold back action (of motor speed and torque) at large conduction phase angle. This is due to the peak current initially increasing when the phase conduction angle is reduced at constant load torque.

Ramp Generator to provide Controlled Acceleration

The ramp generator is a follower integrator design which can be used to control the acceleration rate up to the programmed speed. This can also be used to control the rate of phase angle increase in open loop control systems.

The ramp rate is defined by an internal current source (25 microamps) and the capacitor connected to pin 9.

Warning LED Drive Circuit

The LED drive circuit is designed to drive an LED in series with the device such that the overall current consumption is minimised by utilising the IC drive current to power the LED. Due to the multiplexing technique on pin 5, some additional current will be required when the circuit is used to provide both load current limit and LED drive (this will normally be about 0.5mA).

The LED will illuminate under one of the following two conditions:

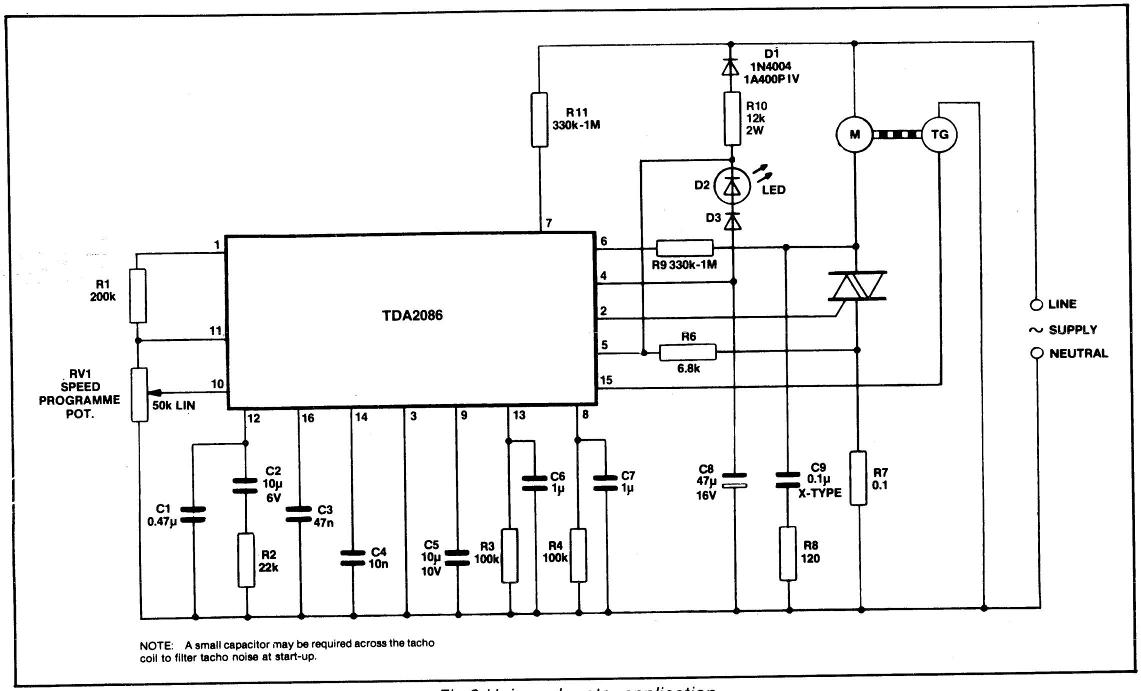
1. The programme speed (or phase in open loop systems) is set for zero.
2. The running speed is less than that programmed.

Hence, indication will be given when the system is powered up but zero power demanded, or when the machine cannot maintain the set operating speed due to the load current circuit operating. The LED will also be illuminated while the soft start function is in operation i.e., the LED will turn off only when the set speed has been reached.

Actual Speed Derived from Tacho Generator Frequency or Analogue Feedback

Tacho frequency or analogue feedback may be used with this device. When frequency feedback is used, the frequency to analogue (F-A) conversion circuit is used. This circuit is extremely linear and tracks the regulated (-5V) supply.

Frequency feedback has the advantage of not being dependent on mechanical clearance, magnetic strength, etc., and since the conversion rate is defined by two external components, accurate speed programming can be obtained without the need for calibration.

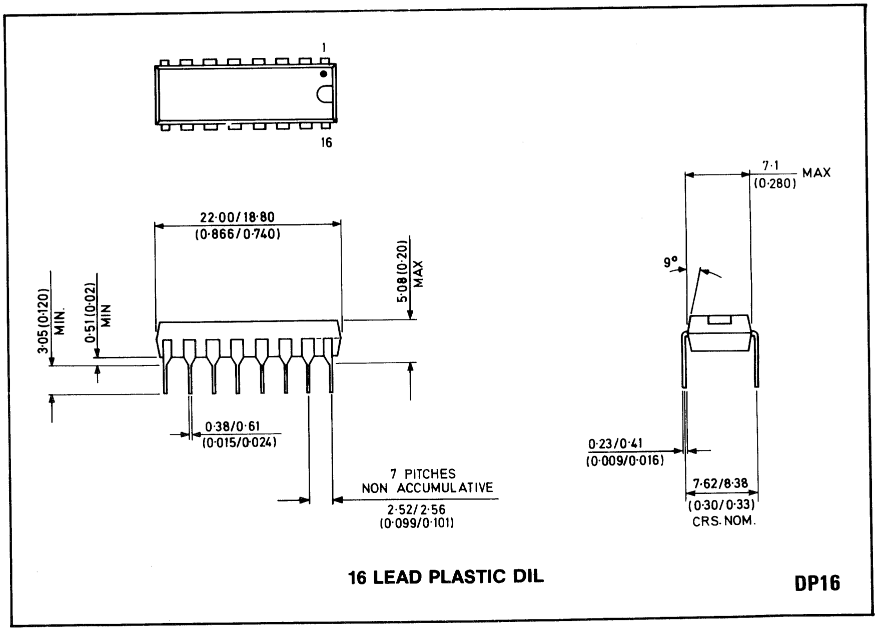


NOTE: A small capacitor may be required across the tacho coil to filter tacho noise at start-up.

Fig.3 Universal motor application

PACKAGE DETAILS

Dimensions are shown thus: mm (in)

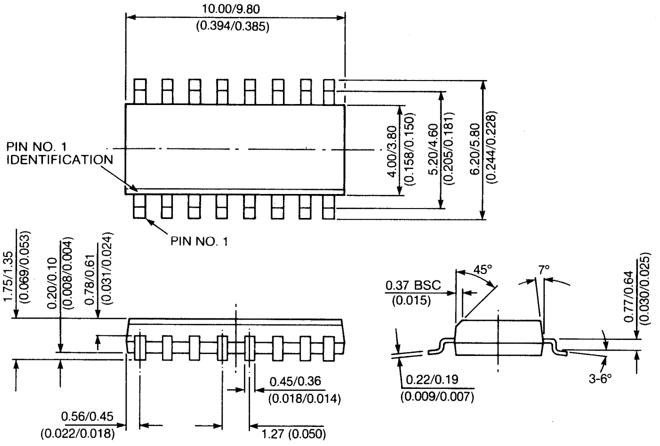


16 LEAD PLASTIC DIL

DP16

PACKAGE DETAILS

Dimensions are shown thus : mm (in)



16 LEAD PLASTIC SMALL OUTLINE DIL **MP16**

System Design

Throughout this section, component references are those shown on the Reference System Circuit Diagram, Fig.4.

OPEN LOOP OPERATION

The simplest method of motor speed control using electronics is an open loop system. In an open loop system, the phase angle of the triac firing pulse is determined by the program input voltage on pin 10. The TDA2085 is particularly useful in open loop applications due to the well-defined control voltage/phase angle relationship. In this mode, changes in motor loading will cause corresponding variations in motor speed but regulation will be a considerable improvement over that achieved when motor speed regulation is obtained by conventional series dropper resistor.

CLOSED LOOP CONTROL

A block diagram of a basic closed loop speed control system is shown in Fig.3. In this case, a voltage proportional to motor speed is compared by the amplifier with the speed program voltage and any difference will cause an appropriate change in firing pulse angle and hence motor speed. In this way automatic compensation for changing motor loads can be made.

In addition to the basic speed control functions mentioned above, additional circuitry is provided to allow control of motor acceleration and reduction of firing pulse phase angle in case of motor overload.

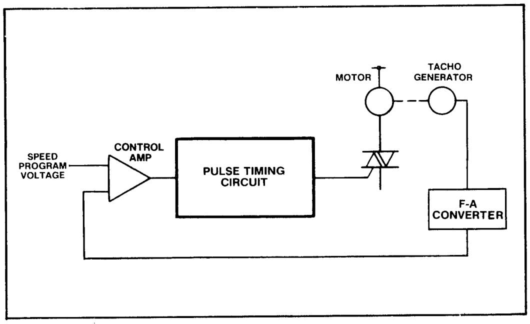


Fig.3 Basic closed loop control system

FEEDBACK VOLTAGE

An analogue feedback voltage of 0V to -5V, obtained by rectifying and smoothing the output from a tacho generator, may be applied to pin 13. If analogue feedback is used, the frequency to analogue converter circuitry must be made inoperative by connecting pin 15 to ground and leaving pin 14 open circuit.

In most motor control applications digital feedback is recommended as this method has the advantage of inherent stability against tacho ageing and temperature drift whilst requiring no speed calibration.

Direct connection of the tacho is possible with perhaps a small capacitor to ground to reject noise, as signal amplitude is unimportant; provided the minimum value is greater than about 350mV peak which is necessary to overcome hysteresis plus input offset voltage.

An open circuit tacho will allow the tacho input to be pulled negative by the bias current until a general reset is initiated at a trip level of about -5.5V. In order to prevent a reset condition during normal operation it is necessary to limit the tacho signal to a value significantly less than the trip level, this being achieved by the capacitor C10 and resistor R6, which are chosen to give a substantially constant input voltage at all speeds.

Frequency to Analogue Converter

The frequency to analogue converter is used with digital feedback to convert the frequency of the tacho input to an analogue voltage suitable for application to the control amplifier.

During negative half cycles at the tacho input, C4 is charged by an internally generated current of nominally 100μA until -5.5V is reached, at which point the capacitor is rapidly discharged. Each time C4 is charged a pulse of current equal to and designed to track with that at pin 14 is integrated at pin 13 by C6, producing a DC voltage proportional to motor speed.

By choosing a suitable conversion factor for the frequency to analogue converter it is possible to design a system to run at any given speed within the 0V to -5V control voltage range at pin 10.

Example: A motor fitted with an 8 pole tacho is required to run at 5000 rev/min with a control voltage at pin 10 of 2.5V. Calculate the values of C4 and R3 required.

Since at steady speed the control voltage at pin 10 and the F-A output voltage at pin 13 must balance, C4 and R3 must be chosen to give 2.5V at pin 13 at a motor speed of 5000 rev/min.

The analogue feedback voltage (Vf) generated by the converter circuit is given by

$$\mathrm{Vf} = \mathrm{Kft} \times 10^{-3}\ \mathrm{Volts} \qquad \text{...1}$$

where K is the conversion factor given by

$$\mathrm{K} = \frac{\mathrm{C4\ \ R3}}{200}\ \mathrm{mV/Hz} \qquad \text{...2}$$

and ft is the tacho frequency given by

$$\mathrm{ft} = \frac{\mathrm{SN}}{120}\ \mathrm{Hz} \qquad \text{...3}$$

using 1 and 3 above

$$\mathrm{K} = \frac{2.5\mathrm{V}}{0.333} = 7.5\mathrm{mV/Hz}$$

choosing R3 = 150kΩ in the range 100kΩ to 470kΩ and using 2 above

$$\mathrm{C4} = \frac{7.5 \times 200}{150\mathrm{k}} = 10\mathrm{nF}$$

Provided close tolerance components are used for C4 and R3, most systems should not need calibration, but if required R3 can be replaced by a series resistor/potentiometer combination to give precise speed adjustment.

The value of capacitor C6 on pin 13 is a compromise between F-A converter response time and ripple voltage at the control amplifier input. In most systems a value of 1μF will be sufficient.

Under some conditions noise introduced into the tacho coil by vibration of the stationary motor armature when power is first applied, or by electromagnetic induction can produce sufficient feedback to prevent motor start up, the

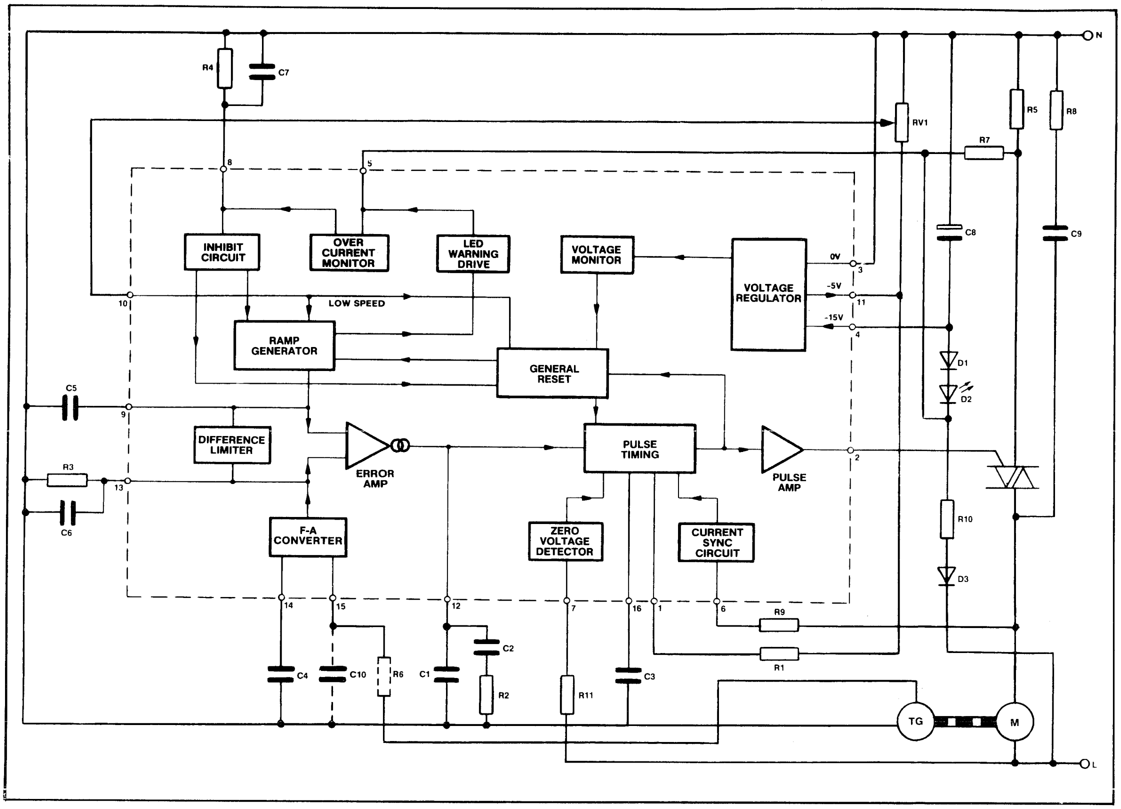


Fig.4 Reference system circuit diagram

phase control system using the tacho noise as evidence that the motor is running. This condition is most likely with the TDA2085A where the tacho is connected directly to pin 15 without a capacitor to ground. A cure can usually be found by connecting a capacitor to ground or in difficult cases a series resistor as well.

RAMP GENERATOR

The ramp generator limits the rate of change of speed reference voltage (Vs) applied to the control amplifier and therefore controls the rate of acceleration of the motor. The ramp rate Vr is set by an internally generated 30μA current source Ir and the capacitor C5 on pin 9, the rate being given by

$$Vr = \frac{Ir \times 10^{-6}}{C10}\ V/s \qquad ...4$$

Using the previous example where the control voltage is increased from zero to -2.5V and with C5 = 10μF the ramp rate (Vr) will be

$$\frac{30 \times 10^{-6}}{10 \times 10^{-6}} = 3.0V/s$$

$$\text{and the acceleration time} = \frac{2.5V}{3.0V/s} = 0.83 \text{ seconds}$$

The final ramp voltage on pin 9 is 2Vbe below the control voltage on pin 10.

SPEED PROGRAM VOLTAGE

The speed program voltage (V10) on pin 10 has a working range from the zero power demand level at -75mV and Vreg. Levels above 75mV on pin 10 will cause the ramp capacitor to remain discharged and the triac drive pulse will be inhibited. The LED on pin 5 will also remain lit.

In most applications pin 10 voltage will be derived from a potentiometer connected between Vreg and ground.

THE CONTROL AMPLIFIER

In closed loop applications, the control amplifier is used to compare the analogue feedback voltage (Vf) at pin 13 with the speed reference voltage on pin 10 and to produce a phase control voltage Vp on pin 12. The amplifier has a transconductance gain of 100μA/V with a limited bidirectional output drive capability of ±25μA. Proportional control therefore occurs for differential input errors between ±250mV.

The gain and phase compensation for closed loop control systems are determined by C1, C2 and R2 on pin 12. These components are best chosen empirically to achieve a compromise in terms of speed overshoot and response time in the actual system.

For open loop control, the control amplifier may be used as a buffer by connecting pin 12 to pin 13 and disabling the F-A converter by grounding pin 15. Use may still be made of the ramp generator to control the maximum rate of phase angle increase.

If required the maximum phase angle can be controlled by a clamp voltage applied to pin 12 but care must be taken to ensure a sharp turn-on knee.

ZERO VOLTAGE DETECTOR

The zero voltage detector resets the pulse timing circuit ramp generator at the zero points of each mains cycle. The mains voltage is applied via a high value current limiting resistor R11 to pin 7 and a reset pulse is generated whenever the input current is between ±50μA.

The circuit is designed to give symmetrical switching about the zero voltage points ensuring symmetrical triac firing in positive and negative mains half cycles.

The value of R11 should be chosen to limit the peak current in pin 7 to less than ±1mA.

CURRENT SYNC CIRCUIT

The current sync circuit operates in conjunction with the pulse timing circuit by supplying an enable signal dependent on the conduction state of the triac. The enable signal is generated if the voltage across the triac is sufficient to produce an input current to pin 6 via R9 greater than ±50μA.

Peak current to pin 6 should be limited to below ±1mA.

PULSE TIMING CIRCUIT

The function of the pulse timing circuit is to control the delay and duration of the triac firing pulse. A ramp voltage is produced on the pulse timing capacitor C3 on pin 16 which is charged by a constant current determined by R1 on pin 1. The ramp is reset by the voltage sync circuit at each mains zero crossing. A triac firing pulse is produced when the ramp voltage reaches a level determined by the control amplifier output on pin 12 unless further delayed by the current sync input pin 6.

Full power may be supplied to inductive loads since, when maximum conduction is demanded, the triac pulse is delayed until the lagging load current from the previous half cycle has reduced to zero. At this point the triac will cease to conduct and the supply voltage will appear across it, which when detected by the current sync input, initiates the next triac pulse.

At high motor speeds brush bounce may become severe, causing interruptions in motor supply current and unlatching of the triac. Under these conditions the current sync circuit will initiate a retriggering pulse to the triac.

The ramp waveform is generated by rapidly charging C3 on pin 16 to a Vbe more negative than Vreg at the mains zero voltage crossing. After the zero voltage point, C3 is discharged in a linear fashion by a current (Id) defined externally on pin 1 by R1. When the voltage on C3 reaches a value determined by the control amplifier on pin 12 a triac gate pulse is initiated. The dynamic working range of the ramp generator is approximately equal to Vreg.

The triac pulse duration is determined by recharging C3 to nominally 50mV above the original trip voltage.

If retriggering occurs the delay will be determined by the time taken for the current Id to discharge C3 back to the original trip voltage.

Triac Pulse Timing Equations

Ramp discharge current

$$\mathrm{Id} = \frac{(\mathrm{Vreg} - \mathrm{Vbe})}{\mathrm{R1}} \times 10^{6}\,\mu\mathrm{A} \qquad ...5$$

Dynamic ramp voltage on pin 16

$$\mathrm{Vrp} = \frac{\mathrm{Id} \times 10^{-6}}{2 \times \mathrm{fm} \times \mathrm{C3}}\ \mathrm{V} \qquad ...6$$

For full phase control the calculated value of Vrp must be less than Vreg.

In most applications standard values can be used for C3 and R1. These are:

For 50Hz supply

C3 = 47nF ± 10%

R1 = 200kΩ ± 5%

For 60Hz supply

C3 = 47nF ± 10%

R1 = 160kΩ ± 5%

With the above components the triac pulse width will be approximately 70μs and the retriggering time 100μs.

TRIAC GATE DRIVE

The triac gate pulse is negative going, this being preferred by triac manufacturers and in most cases it will be found that the triggering current requirement is less for negative pulses. Internal current limiting is provided, the current being largely independent of the triac gate voltage although a series resistor can be used to reduce overall power consumption if required.

When a series resistor is used the approximate gate drive current may be calculated from

$$\mathrm{Itg} = \frac{\mathrm{V4} - 1 - \mathrm{Vtg}}{\mathrm{Rg}} \times 10^{3}\mathrm{mA} \qquad ...7$$

provided the series resistor is sufficient to reduce the gate current below the internally limited value.

TRIAC LATCHING

As mentioned before, it is necessary to trigger the triac when conditions are right for a latching current to be established within the period of the gate pulse.

When switching on an inductive load the initial current will increase from zero at a rate dependent on the voltage across and the inductance of the load (the minimum voltage being determined by the load current detector). To help with latching, additional triac load current for a short duration can be provided if required by means of a series RC network in parallel with the triac. C9 and R8 provide this function as well as offering some protection from dv/dt triggering of the triac due to noise spikes on the mains.

LOAD CURRENT LIMITING

The purpose of motor current limitation is more to protect the triac than the motor itself. Since the stall current is generally much higher than that required for maximum working torque, a limitation can be set at a lower value thus guaranteeing safe operation of the triac under all load conditions.

The load current is normally sensed in the positive mains half cycle by means of a low value resistor R5 in series with the triac and load. This voltage drop is converted back into a low current source by R7 in series with pin 5 and is mirrored internally with a ratio of 2:1 into pin 8. Peak current limiting can be provided at this point by inserting a resistor between pin 8 and common whereas average current limiting requires the addition of an integrating capacitor.

When average current limiting is used the double action of the inhibit circuits on pin 8 is utilised. This has two trip points at -1V (load current limit) and -1.5V (load current inhibit). When the first trip point (-1V) is reached the power to the load will be gradually reduced by decreasing the voltage on the ramp capacitor, (the discharge rate being equal but opposite to the soft start), hence reducing the power and providing a constant current drive (producing constant torque) to the motor. When the second trip point (-1.5V) is reached a general reset of all timing functions occurs at a fast rate, hence if a gross overload was suddenly applied to the motor, a rapid reduction in power supplied would result. Since it is not possible to turn the triac off during a cycle, the triac and motor should be chosen to be capable of withstanding one complete mains cycle under the worst overload condition.

The value of R5 can be calculated from

For load current limit

$$\frac{\frac{1}{R4} \times R7}{\text{Average load current} \times 0.25} \qquad \ldots 8$$

For load current inhibit

$$\frac{\frac{1.5}{R4} \times R7}{\text{Average load current} \times 0.25} \qquad \ldots 9$$

The value of R4 can vary between 100kΩ and 470kΩ, the lower value being preferred in order to reduce offset voltages produced by pin 8 bias current. When the LED drive capability of pin 5 is used the overload current level will be increased by about 20%.

In high current applications where the power dissipated in a series sensing resistor would be unacceptable, a current transformer may be used as shown in Fig.5.

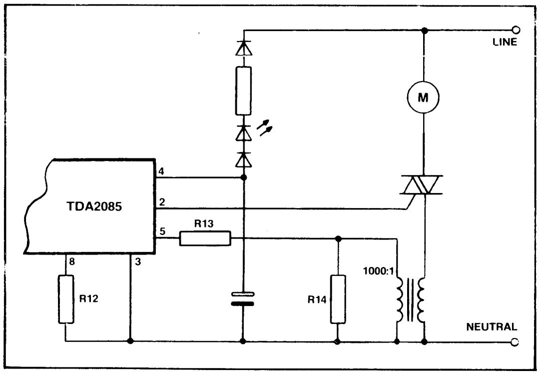


Fig.5 Current transformer application

With a 1000:1 current transformer the average overload current can be calculated from

For load current limit

$$\frac{4 \times 1000 \times R13}{R14 \times R12} \qquad \ldots 10$$

For load current inhibit

$$\frac{4 \times 1.5 \times 1000 \times R13}{R14 \times R12} \qquad \ldots 11$$

Suitable values for R12 and R13 are 100kΩ and 5.6kΩ.

Peak load current limiting tends to produce a foldback action (of motor speed and torque) at large conduction phase angles. This is due to the peak current initially increasing when the phase conduction angle is reduced at constant load torque. If peak current limiting is adequate, capacitor C7 can be removed and the peak overload current calculated from

$$\frac{R7 \times 1.5}{R5 \times R4 \times 0.5} \qquad \ldots 12$$

INHIBIT CIRCUIT

As previously stated the inhibit circuit has two trip levels normally used in load current limiting but if required a general reset can be initiated by the application of a voltage between -1.5 and -Vreg to pin 8. This feature allows on/off control by external control circuitry or the fitting of a PTC thermistor to sense motor winding temperature as shown in Fig.6. At normal temperatures pin 8 is held close to the 0V rail as the thermistor resistance is low, but as the thermistor critical temperature is approached, the resistance increases rapidly until pin 8 voltage falls below -1.5V when the power to the load is removed.

LED DRIVE CIRCUIT

The LED drive circuit is designed to drive an LED in series with the device such that the IC supply current is used to drive the LED thereby minimising overall power consumption.

In order to turn the LED off an internal circuit with a voltage drop lower than the LED plus its associated silicon diode is used to shunt current from the LED.

Due to the multiplexing technique used on pin 5 whereby IC supply current is provided during negative half cycles and load current monitoring during positive half cycles some additional current, usually amounting to about 0.5mA will be required when the LED drive facility is used.

Due to SCR latching associated with the LED drive circuit it is not possible to use the LED feature with or without load current limiting if the circuit is powered from DC supplies.

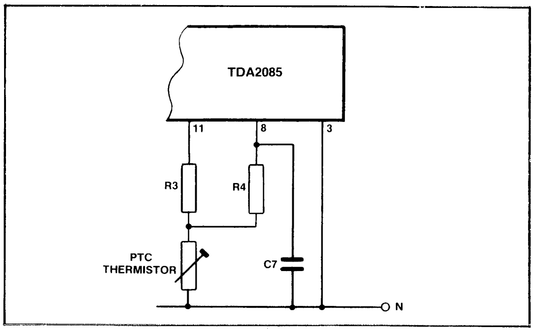


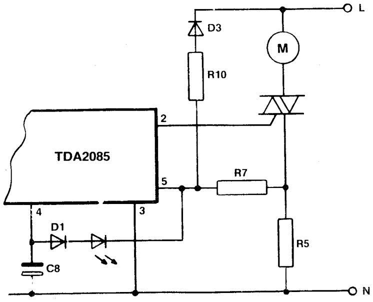
Fig.6 Over-temperature shut-down

AC SUPPLY CIRCUITS

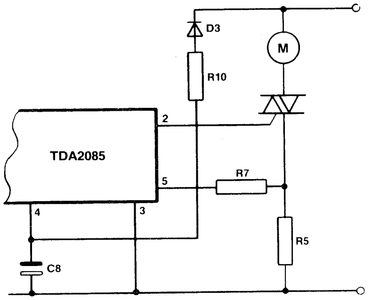
The TDA2085 circuit has been designed for very low power consumption, this parameter being particularly important when operating from mains voltages via a dropper resistor.

When calculating the value of dropper resistor required additional currents such as those required by the control potentiometer on pin 10 or any other ancillary circuitry powered from the -5V or -15V supplies must be added to the IC supply current.

The circuit design whereby all critical control circuitry is powered from a -5V series stabilised supply ensures that the circuit is insensitive to ripple on the -15V line, thus enabling a single dropper resistor and capacitor to be used as shown in Fig.7.



(a) With LED



(b) Without LED

Fig.7 Mains supply circuits

Component values can be calculated from

$$C8 = \frac{Is}{Vcr \times fm} \times 10^3 \mu F \qquad ...13$$

$$R10 = \frac{\frac{\sqrt{2}}{\pi} Vac - Vcc}{Is\ (mA)} \times 10^3 \Omega \qquad ...14$$

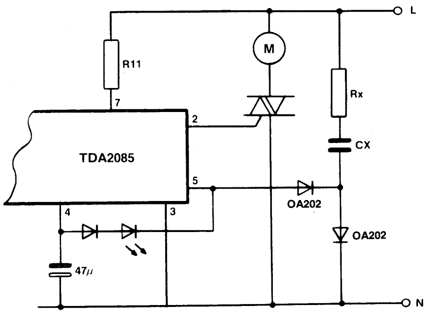
$$Pdr = \frac{(\sqrt{2}\ Vac - Vcc)^2}{4R10}\ W \qquad ...15$$

The low current requirement of the TDA2085 reduces the power dissipation in the mains dropper resistor to below 2W, but in some cases even this level of power can be undesirable. By using a reactive feed arrangement the power loss in the dropper resistor is eliminated, but due to the phase shift introduced by the reactive feed capacitor, the multiplexing of current overload and LED drive on pin 5 will not function.

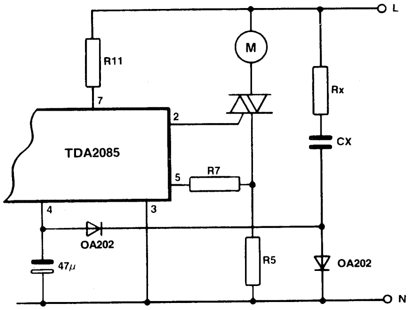
Figure 8a shows a reactive feed using the LED drive feature, and Fig.8b reactive feed with current overload.

The value of Cx can be calculated from

$$Cx = \frac{Is\ (mA)}{fm\ (2\sqrt{2}\ Vac - Vcc)} \times 10^3 \mu F \qquad ...16$$



(a) With LED drive



(b) With current overload

Fig.8 Reactive feed circuits

Resistor Rx is included to limit current due to noise spikes on the supply, a value of 330Ω being suitable.

OPERATION FROM DC SUPPLIES

Operation from stabilised or unstabilised DC supplies is possible provided a signal in phase with the mains is available to drive the voltage sync input on pin 7.

If a stabilised supply is used, the voltage must always be set between the maximum shunt stabiliser voltage on pin 4 and the minimum voltage monitor enable level. Supplies outside these limits will prevent circuit operation or cause damage to the chip through excessive power dissipation.

When operation from an unstabilised DC supply is required, the circuit shown in Fig.8 should be used, R1 value being calculated from

$$\frac{Vss - Vcc}{Is\ (mA)} \times 10^3 \Omega \qquad ...17$$

To ensure a relatively constant current through R1 the unstabilised DC supply should be considerably higher than the shunt stabiliser voltage.

NB Worst case conditions should be used in the above equations.

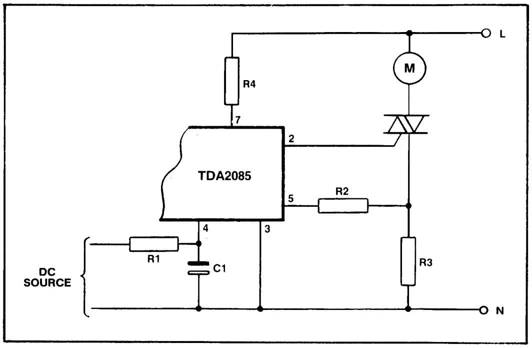


Fig.9 Operation from unstabilised DC

SYMBOLS USED IN TEXT

Symbol	Function	Units
fm	Mains Frequency	Hz
ft	Tacho Frequency	Hz
Id	Pulse Ramp Discharge Current	μA
Ir	Ramp Current	μA
Is	Supply Current	mA
Itg	Triac Gate Drive Current	mA
K	Tacho Conversion Factor	mV/Hz
N	No. of Tacho Poles	-
Rg	Series Triac Gate Resistor	OHMS
S	Motor Speed	RPM
Vac	AC Supply Voltage (RMS)	V
Vbe	Transistor Base Emitter Voltage	V
Vcc	Negative Rail Voltage Pin 4	V
Vcr	Supply Ripple Voltage	V
Vf	Analogue Feedback Voltage	V
Vp	Phase Control Voltage	V
Vr	Ramp Rate	V/s
Vreg	-5V Series Stabiliser Voltage (Pin 11)	V
Vrp	Dynamic Ramp Voltage	V
Vs	Internal Speed Reference Voltage	V
Vss	Unstabilised DC Supply Voltage	V
Vtg	Triac Gate Voltage	V
V10	Speed Program Voltage on Pin 10	V

Motor Control Applications

UNIVERSAL MOTOR APPLICATIONS

Figure 10 shows a typical universal motor closed loop speed control circuit suitable for use in domestic appliances such as food mixers or in electric drills. The circuit is basically that in the reference system diagram with the addition of component values which, with an 8 pole tacho give a speed range from zero to 15000 rev/min.

OPEN LOOP CONTROL

Where an existing tapped resistor speed control is being updated or where speed regulation is relatively unimportant, an open loop control system may be adequate and provide a lower cost solution. A basic open loop system is shown in Fig.11, but if required, the LED and current overload circuits shown in Fig.10 may be added.

OPTICAL FEEDBACK

Most applications utilise a feedback signal derived from a tacho generator but there is no reason why other systems cannot be used. Figure 12 shows how a slotted optical coupler can be interfaced with few additional components. The feedback signal is produced by interrupting the light from the LED using a perforated disc attached to the motor shaft. By connecting the LED in series with the IC, sufficient current for operation is available without increasing dissipation in the mains dropper resistor. The capacitor and resistor associated with the LED are required to provide a smooth DC supply.

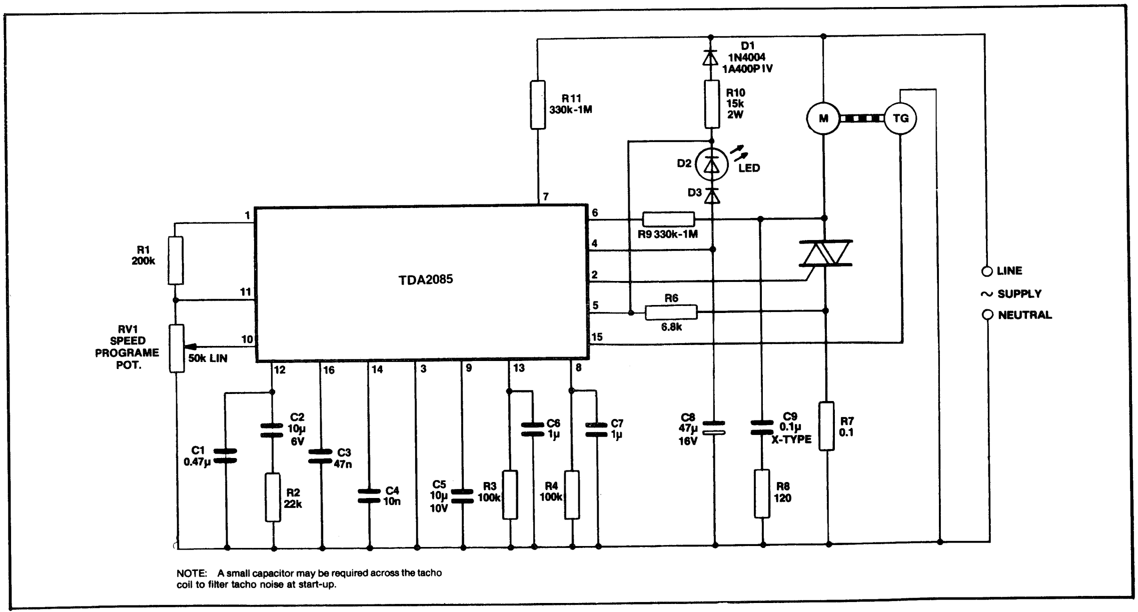
CURRENT FOLDBACK

In some applications it is desirable to reduce the current overload point as the motors speed is reduced, preventing the possibility of the motor overheating due to reduced fan cooling. Figures 13 and 14 show two possible methods of achieving foldback operation, together with graphs indicating the degree of overload current reduction for various component values.

Both circuits give similar results with the exception that the version shown in Fig.14 produces a fixed current overload point at settings close to maximum phase angle. This constant overload point will extend over about 15% of the control range.

SYSTEMS INTERFACING

The 5V stabilised supply available from the TDA2085 allows standard CMOS logic elements to be powered directly thus enabling easy interface to a logic control system. Figure 15 shows a method of providing 16 speeds controlled by a 4 bit binary input from an isolated digital system. Digital information is transmitted via opto isolators to a single CMOS circuit powered from the TDA2085, any 4 bit binary counter or latch being suitable. A simple D-A converter using an SL3046 transistor array produces a 16 step analogue output suitable for direct connection to the TDA2085 control input. Where only on/off control is required, this can be accomplished by connecting pin 8 to -5V by using a transistor or relay contacts as shown in Fig.16a if the current limit on pin 5 is being used or by direct connection of a CMOS gate as inFig.16b if current limiting is not employed. This method of control discharges the ramp capacitor at switch off, allowing controlled acceleration when power is again demanded.



NOTE: A small capacitor may be required across the tacho coil to filter tacho noise at start-up.

Fig.10 Universal motor application

CONTROL OF TEMPERATURE

Although the TDA2085 is primarily designed for speed control of electric motors, other types of load such as heating elements or lighting may also be controlled. Figure 17 shows a circuit for temperature control where the voltage on pin 13 set by a fixed resistor and NTC thermistor is compared with the reference voltage on pin 10. The value of Rt should be chosen to give equal voltages at pins 10 and 13 when the thermistor is at the required temperature. Care must be taken to ensure adequate RFI suppression is provided when using the TDA2085 to control resistive loads.

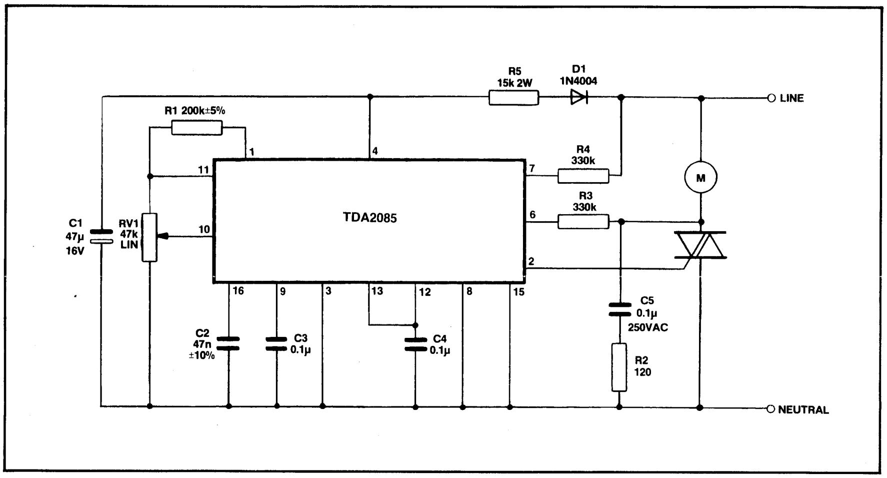


Fig.11 Open loop application, 240V

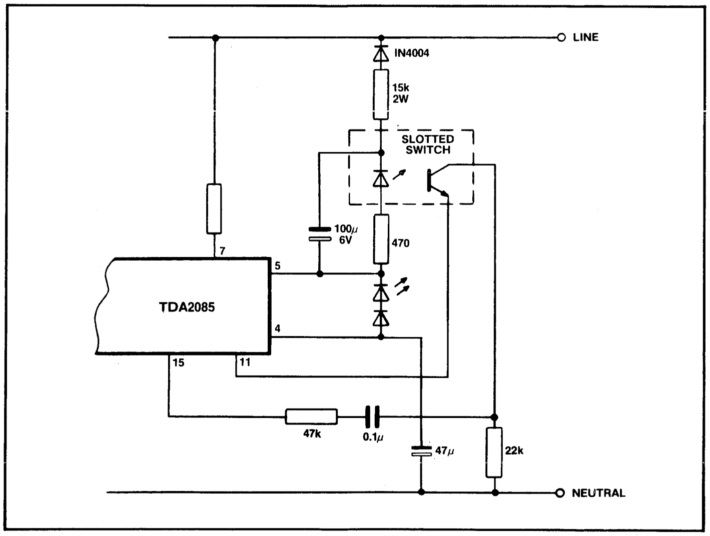


Fig.12 Optical feedback application

MOTOR REVERSING

When the TDA2085 is used in electric drills it is sometimes a requirement to reverse the direction of rotation. Unless some kind of interlock between the reversing switch and the on/off control is fitted, it is possible to damage the motor by operating the reversing switch whilst the motor is still running. To overcome this problem, it is necessary to remove power from the motor automatically when the reversing switch is operated.

It is not possible to give a precise method of achieving this as the best method depends on the design of the drill and the number of spare contacts available on the reversing switch. However in general the requirement is to rapidly discharge the soft start capacitor allowing the motor to come to rest and then to accelerate gently in the new direction.

Two methods of discharging the soft start capacitor are recommended.

1. Momentarily take pin 10 to within 50mV of the 0V rail (pin 3).
2. Momentarily take pin 8 more negative than the load current inhibit voltage with respect to pin 3. This is typically 1.5V.

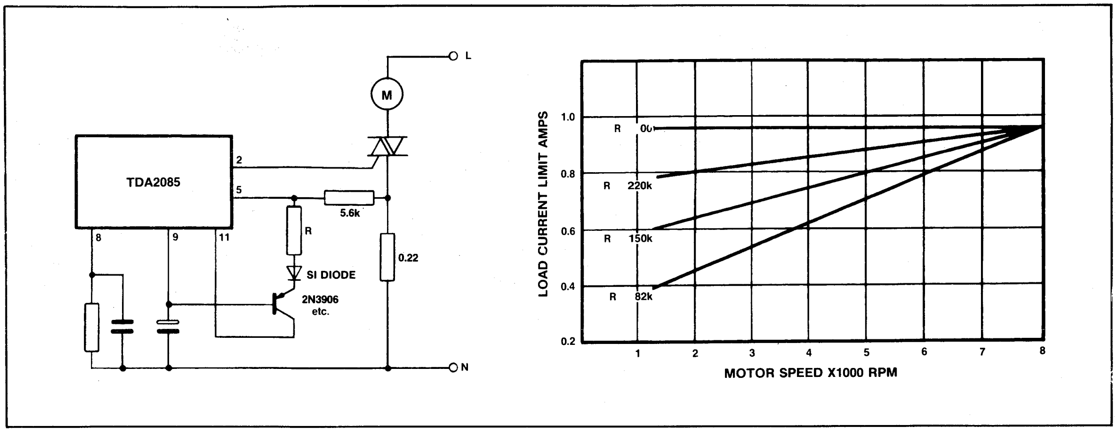


Fig.13 Current limit foldback, method 1

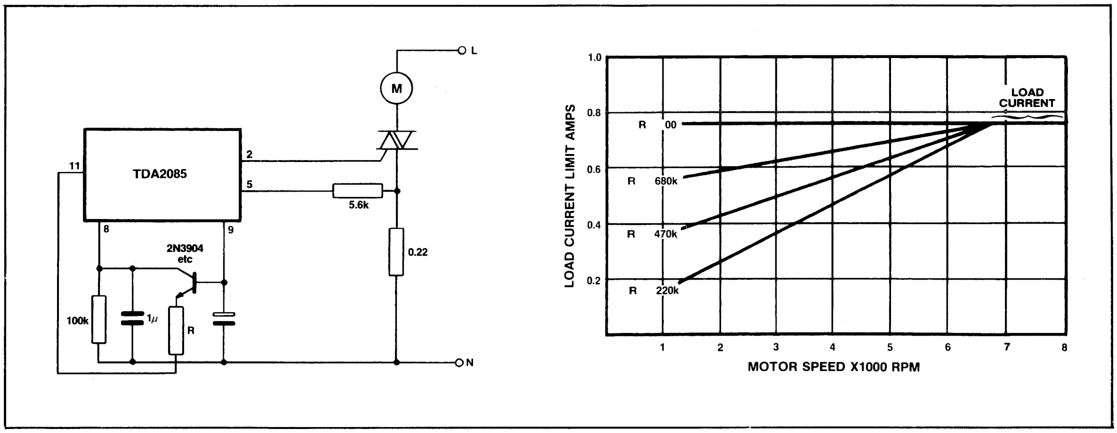


Fig.14 Current limit foldback, method 2

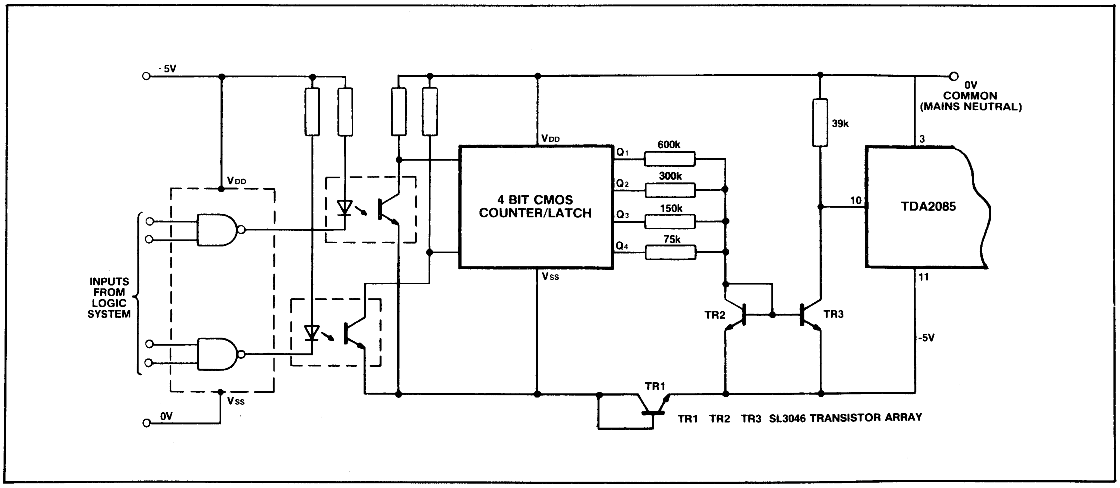


Fig.15 Interface to digital system

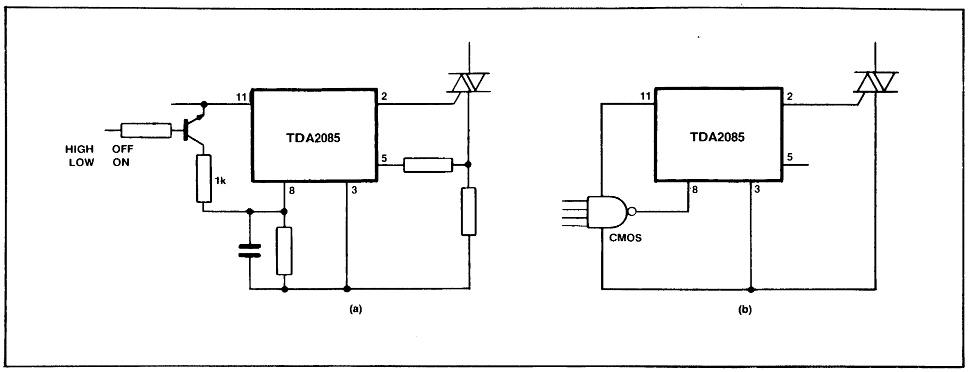


Fig.16 On/off control

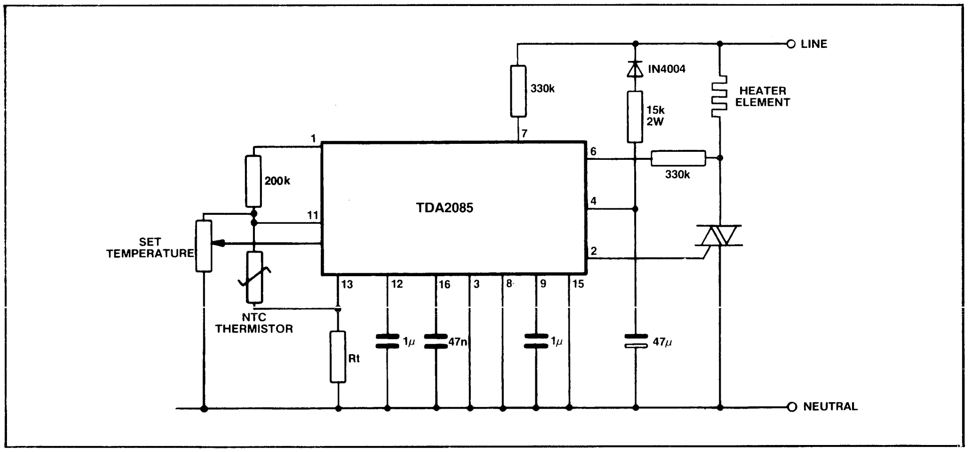


Fig.17 Temperature control application

START UP DELAY

It is sometimes possible to observe a finite time delay between the application of power to the tool and the motor starting to run. The problem is usually seen in closed loop applications and seems to affect some motors more than others.

There is no wholly satisfactory solution to this problem which is basically caused by the fact that many universal motors do not begin to turn until the applied voltage is much as 30 % of their full working voltage. At switch-on, the soft start and compensation circuit capacitors are all discharged; these capacitors must reach such a charge that the output of the error amp is about 1.5V before the motor will begin to rotate - this is the source of the time delay. Obviously, motors with large mechanical time constants (low -3dB frequency on their Bode Plot) will require heavy compensation and thus will be slow to start.

The problem can be alleviated by using a different compensation circuit from the one in Fig.10. The circuit in Fig.18 applies negative feedback around the error amplifier to generate the roll-off at HF, rather than slew-limiting the output as does the circuit of Fig.10. The component values shown are typical for a large (700W) electric drill. With this circuit it was found that a satisfactory soft start was obtained without having to have a large capacitor on pin 9. The additional advantage of this technique is that no electrolytic capacitors are needed apart from the main smoothing capacitor.

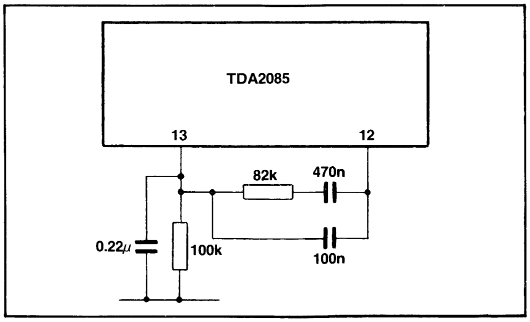


Fig.18

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TDA2088

PHASE CONTROL INTEGRATED CIRCUIT FOR CURRENT FEEDBACK APPLICATIONS

The TDA2088 EXP is a bipolar integrated circuit phase controller, optimised for use in current feedback applications. It can also be used in open loop mode. The circuit was primarily designed for motor speed control in applications such as power tools and domestic appliances (foodmixers etc.).

FEATURES

- Powered Direct from AC Mains or DC Line
- -5V Supply Available for Ancillary Circuitry
- Low Supply Current Consumption
- Negative Triac Firing Pulses
- Guaranteed Minimum 100mA Triac Drive Current
- Well-Defined Control Voltage/Phase Angle Relationship
- Speed Compensated by Sensing Motor Current
- Simple Optimisation of Control Loop Parameters

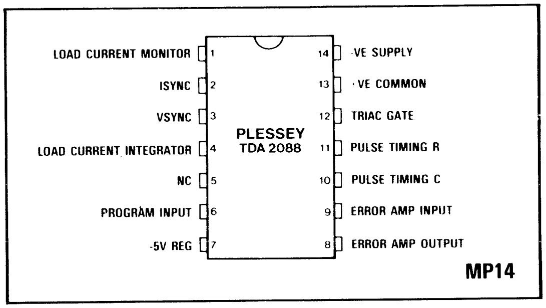


Fig.1 Pin connections - top view

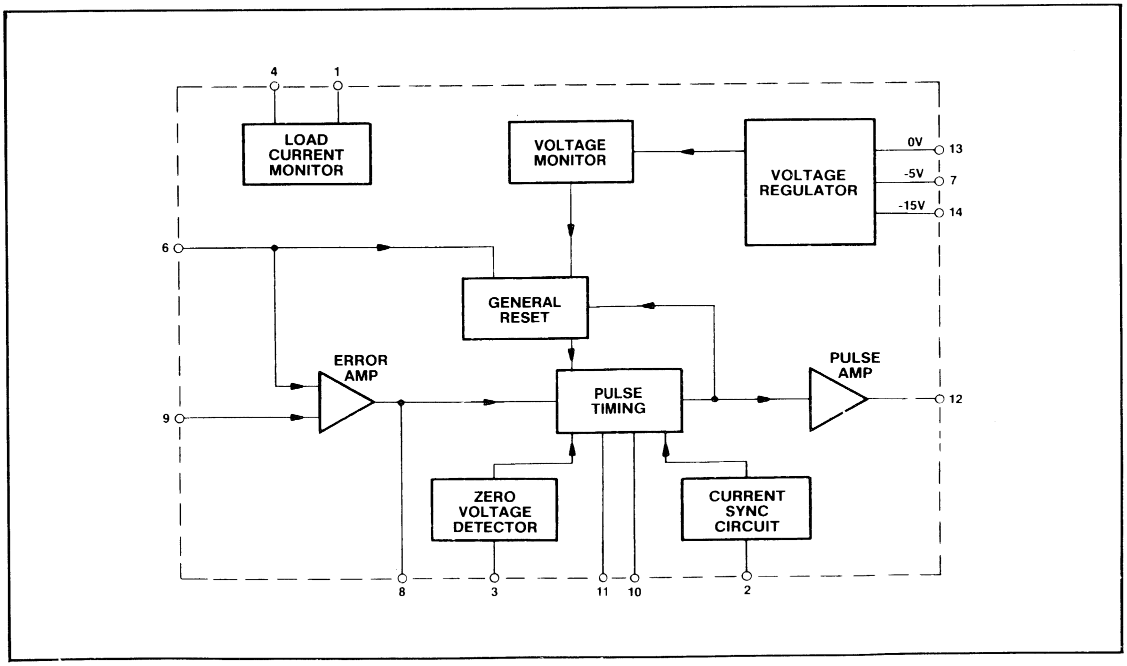


Fig.2 Block diagram

ELECTRICAL CHARACTERISTICS

Test conditions (unless otherwise stated):

$T_{amb} = +25°C$

All potentials measured with respect to common (Pin 13) (unless otherwise stated)

Characteristic	Value			Units	Conditions
	Min.	Typ.	Max.		
CURRENT CONSUMPTION					
Pin 14					
IC operating current		2.8	3.8	mA	Includes triac gate current for 50μs pulse
SHUNT VOLTAGE REGULATOR					
Pin 14					
Regulating voltage	-16	-14.75	-13.5	V	Full temperature range
Voltage monitor enable level	-11		-9	V	
SERIES REGULATOR					
Pin 7					
Regulating voltage (Vreg)	-5.35	-5	-4.65	V	1mA external load
Temperature coefficient			±1	mV/°C	
External load			10	mA	
Regulation	-75		+75	mV	For 0-5mA external load change
SPEED PROGRAM INPUT					
Pin 6					
Input voltage range	Vreg -0.5		0	V	
Input bias current			1	μA	
Zero power demand voltage	-100	-75	-50	mV	
ERROR AMPLIFIER					
Pin 6, 8 and 9					
Input offset voltage	-5		+15	mV	$V_6 - V_9$ to give $I_8 = 0$
Transconductance	80	100	120	μA/V	
Pin 8					
Output current drive	±20		±35	μA	
FIRING PULSE TIMING					
Pin 3					
Voltage SYNC trip level	±35	±50	±65	μA	
Pin 2					
Current SYNC trip level	±35	±50	±65	μA	
Pin 8					
Phase control voltage swing	Vreg		0	V	
Pin 10					
Firing pulse width		50		μs	C pin 10 = 47nF
Pulse repetition time		100		μs	C pin 10 = 47nF, R pin 11 = 200k
FIRING PULSE OUTPUT					
Pin 12					
Drive current	100	125	150	mA	Pin 12 V = -3V
Leakage current			10	μA	Pin 12 V = 0V
LOAD CURRENT SENSING					
Pin 1					
Offset voltage			±20	mV	
Pin 1 and 4					
Current gain	0.475	0.5	0.525		Pin 1 current = 100μA

ABSOLUTE MAXIMUM RATINGS

ELECTRICAL	Value	Units
Triac gate voltage pin 12	4	V
Repetitive peak input current pin 14	80	mA
Non repetitive peak input current pin 14 (tp = 250μs)	200	mA
Non repetitive peak input current pin 1 negative half cycle (tp 250μs)	200	mA
Peak input current (ISYNC) pin 2	±1	mA
Peak input current (VSYNC) pin 3	±1	mA
-5V regulator current pin 7	10	mA
Control amp input voltage pin 9	Vreg	V
THERMAL		
Operating ambient temperature	0 to +85	°C
Storage temperature	-55 to +125	°C

SPECIAL FEATURES

Low Supply Current Consumption

Due to the low current consumption of the device the power dissipation in the mains dropper resistor may be as low as 1.1W on a 220V AC supply (0.5W on 110V).

By incorporating both a shunt and a series voltage regulator in the IC design, a high ripple voltage can be accommodated on the supply smoothing capacitor.

The combination of the above two features result in reduced size and a minimum count of components used in the power supply circuitry.

Powered Direct from AC Mains or DC Line

This device incorporates a shunt regulator (-15V) such that it may be powered from an AC or DC supply via current limiting components or the device may be powered direct from a -12V DC supply.

-5V Supply available for Ancillary Circuitry

A -5V series regulator is incorporated to provide a smooth supply for the internal analogue control functions. This supply may be used externally to power ancillary circuitry such as timing circuits and other logic control circuits etc, as well as driving potentiometers for the analogue control inputs.

Due to this supply technique, greater symmetry between positive and negative half cycle firing phase angle will result.

Low Supply Inhibit Circuit

Timing functions and triac gate drive pulses are inhibited until there is sufficient supply voltage across the device to guarantee complete gate drive pulses.

This ensures that bulk conduction is established in the triac and correct linear operation of the control system is maintained.

Negative Triac Gate Firing Pulses

Since the device works with the positive supply as common, the triac gate pulses are negative going. This is an advantage when selecting a suitable triac since most triac manufacturers prefer this drive polarity.

The device is designed to give a triac pulse that is greater than 100mA for a period of 50 microseconds with standard pulse timing components (47nF, pin 10). Repeated triac gate pulses are given if the triac fails to latch or becomes unlatched due to motor brush bounce.

Well-Defined Control Voltage/Phase Angle Relationship

An internal -5V reference circuit is used as the charging voltage for the pulse timing ramp capacitor and as the reference voltage for the speed input potentiomter. This ensures that maximum phase angle can be obtained by adjusting the resistor or capacitor on the pulse timing circuit, without affecting the maximum setting.

Average Load Current Sensing

The load current is normally sensed in the positive mains half-cycle by means of a low impedance resistor in series with the triac and load. The voltage drop across this resistor is converted back into a low current source by a second resistor and fed into the load current sensing input (pin 1) of the IC. In high load current applications where the power dissipated in a series sensing resistor would be unacceptable, a current transformer may be utilised.

CIRCUIT DESCRIPTION

The current fed into the sensing input (pin 1) is half-wave rectified, then mirrored by the current monitor and fed to pin 4 where it is averaged by an RC network. The magnitude of the current supplied by pin 4 is half that of the input on pin 1. The amount of current feedback can be adjusted by altering the ratio of the input and output resistors on the current monitor. Control loop compensation in most cases can be achieved by the RC averaging network on pin 4 alone, though additional HF loop roll-off can be achieved by loading pin 8 with a series RC network, since the output of this amplifier is current limited.

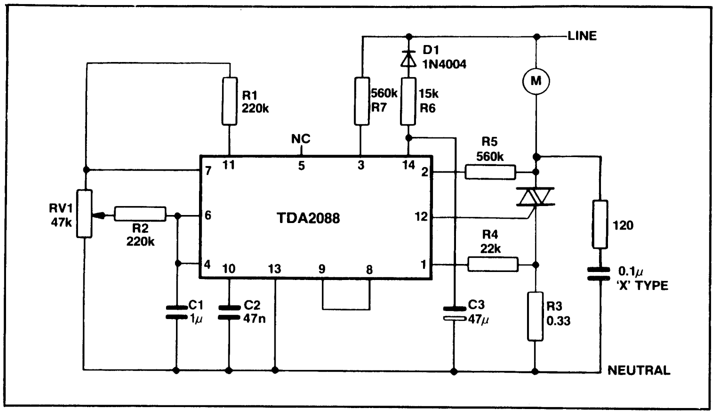
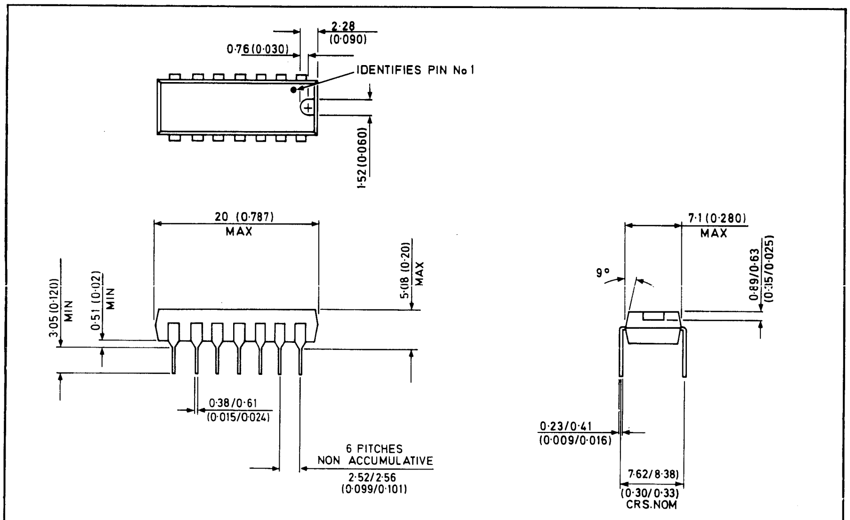


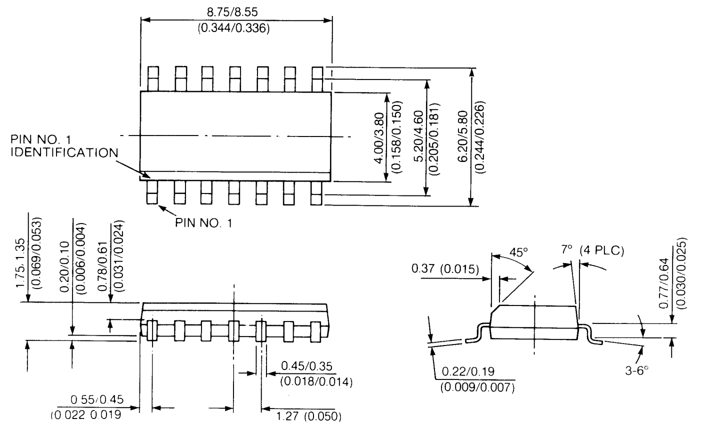
Fig.3 Typical application diagram

PACKAGE DETAILS

Dimensions are shown thus: mm (in)



14 LEAD PLASTIC DIL **DP14**



14 LEAD PLASTIC SMALL OUTLINE DIL **MP14**

System Design with the TDA2088

The TDA2088 is a phase control integrated circuit optimised for current feedback control of small universal motors such as are found in small power tools and food mixers. A derivative of the TDA2086 design, it has a guaranteed minimum 100mA negative triac gate drive capability, and is thus capable of driving up to 40A triacs without pilot triacs or transistor buffers.

Figure 4 shows a typical application for variable speed control of a small universal motor.

CURRENT FEEDBACK

Figure 5 shows the feedback arrangement from Figure 4 in more detail. Component values have to be determined empirically for individual motors but the following guidelines will help.

The power dissipation in R_3 obviously has to be kept low, i.e. its value must be as low as possible, but to avoid significant speed errors from device to device the volt drop across R_3 under normal operating conditions should be >150mV so that the offset on Pin 1 (±20mV max) does not affect the feedback.

The feedback and control currents are summed at pin 6 which can draw a bias current as high as 1μA. For reasonable consistency, $V_{in}/(R_2+Z_{out})$ should be at least 10μA at the operating speed.

Loop compensation and the integration of the feedback current pulses are effected by the capacitor C. This component should be of good quality and low leakage since it must not load the current summing node. A time constant (R_2+Z_{out}) C of 0.25s is probably a good starting point for most motors. Time constants of less than 60ms should not be attempted since the ripple on the feedback component will almost certainly cause instability.

The amount of current feedback is determined by the value of R_3 and the ratio of R_4 to (R_2+Z_{out}). An easy procedure to use is to determine R_3, R_2 and Z_{out} from the considerations above, choosing a large value for R_4 (very little feedback), then reduce R_4 till a satisfactory speed regulation performance is obtained.

Where variable speed operation is required it is often found that the optimum degree of feedback is different for different speeds. This problem can be reduced by using the variation in Z_{out} with control setting to alter the feedback ratio.

The circuit of Figures 4 and 5 produces a characteristic where the feedback is at a maximum at mid-speeds and reduces at higher or lower settings. Figure 6 shows an arrangement where the amount of feedback decreases with increasing speed. Figure 7 is the converse case where feedback increases with increasing speed.

In applications where switched speeds are required (See Figure 8) then the feedback can be optimised for each speed by choosing the ratios of the resistors $R_A:R_B$, $R_C:R_D$, $R_E:R_F$, to give the desired speeds, and the values of $R_A//R_B$, $R_C//R_D$, $R_E//R_F$ to give the desired feedback factors.

Figure 9 shows the most basic form of open-loop speed control with no current feedback.

Figures 10 and 11 shows a pcb layout and component overlay for the schematic shown in Figure 4.

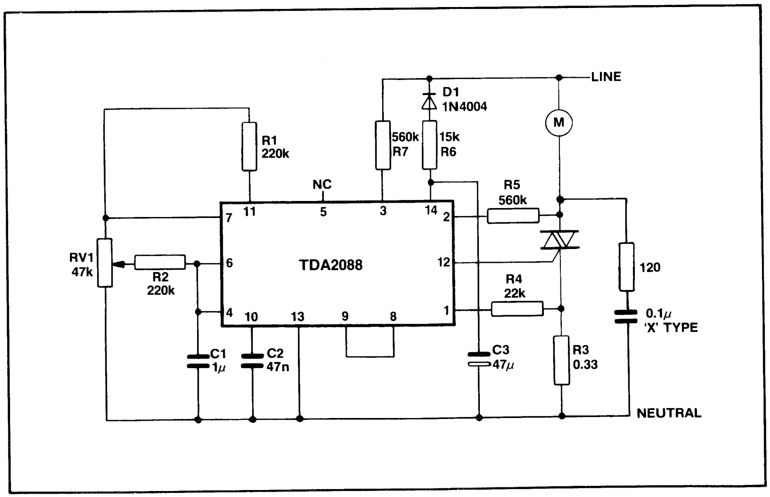


Fig.4 Universal motor speed control using current feedback

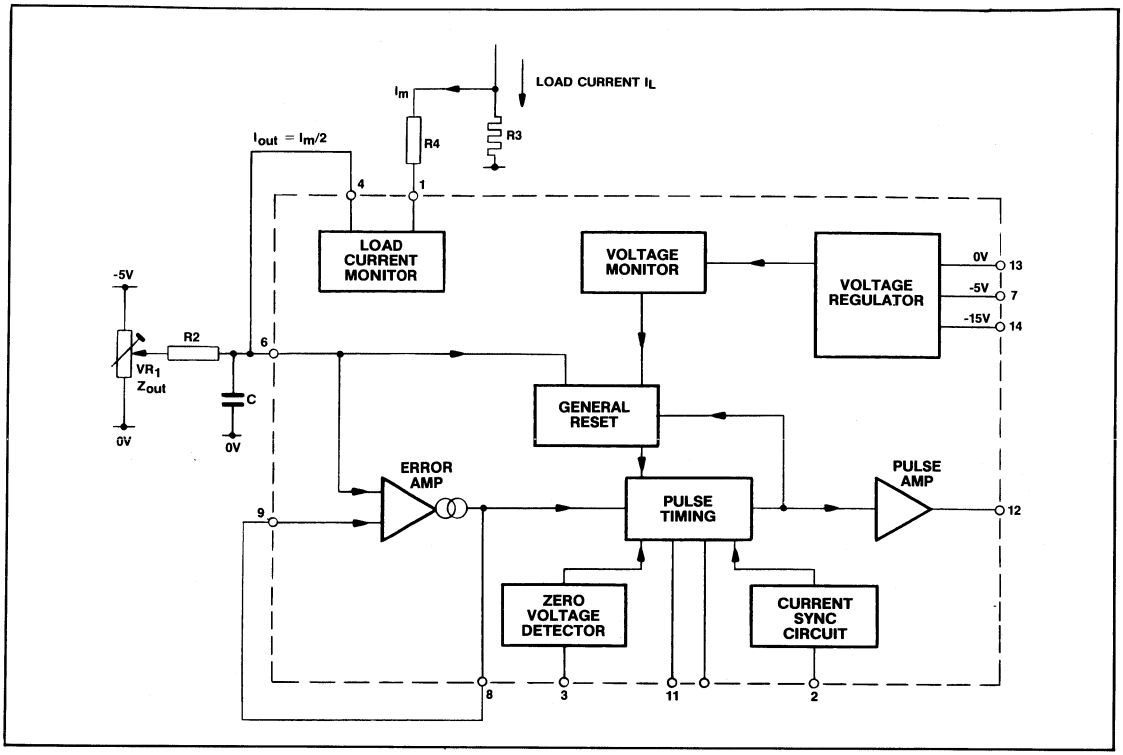


Fig.5 Feedback arrangement

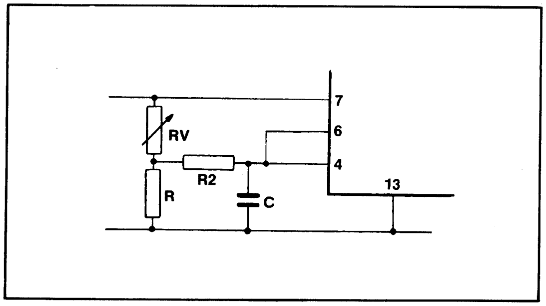


Fig.6

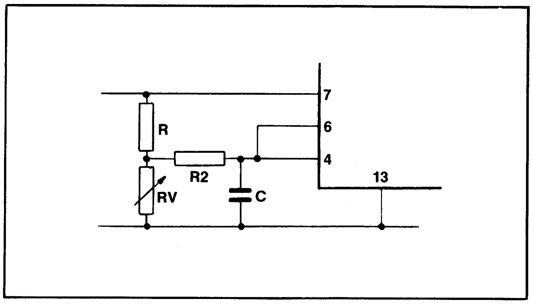


Fig.7

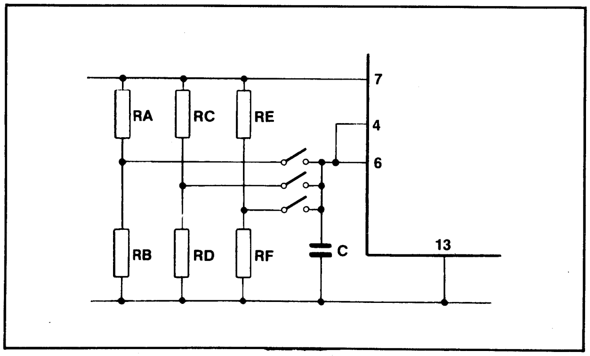


Fig.8

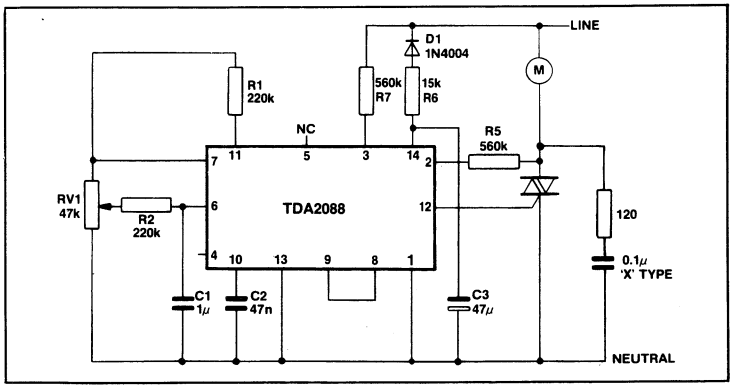


Fig.9 Open-loop speed control

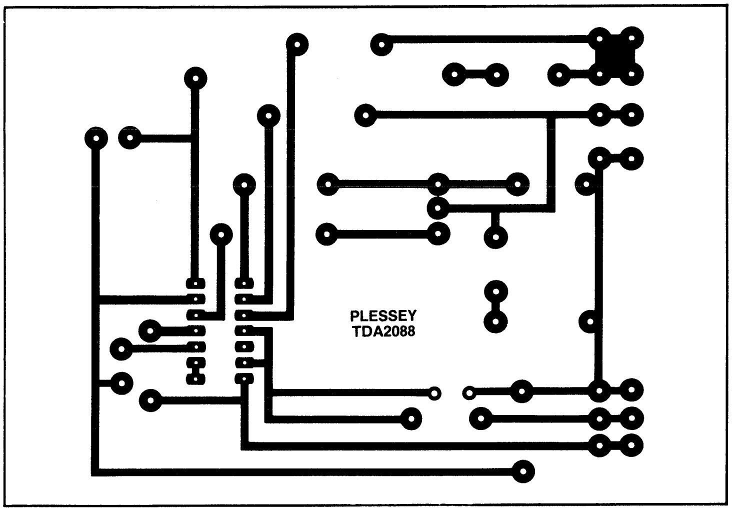


Fig.10 PCB layout for figure 4

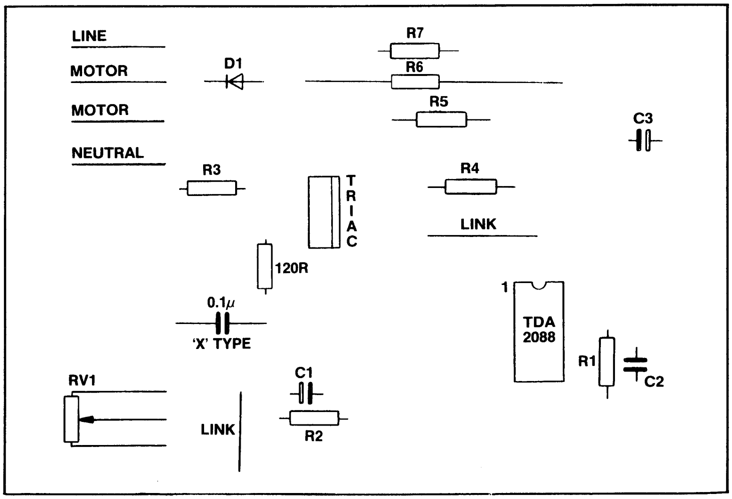


Fig.11 Component overlay for figure 4

TDA2090A

ZERO VOLTAGE SWITCH

The TDA2090 is a symmetrical burst control zero voltage switch designed for temperature control in smoothing irons, water heaters, refrigerators, room heaters etc.

The circuit is designed to eliminate half wave firing and has a programmable switching rate to eliminate lamp flicker (EN50.006, BS5406, 1976).

FEATURES

- 3 LED Drive Circuit Indicates High, Low or In-band for Controlled Temperature
- Symmetrical Negative Triac Firing Pulses about the Mains Zero Voltage Points to Minimise RFI
- Programmable Switching Rate, Proportional Band and LED Indicator Window
- -5V Supply for Sensing, Thermistor Bridge and Ancillary Control Circuits
- Open Circuit Sensor Thermistor Detector demands Zero Power and Lights Over-temperature LED
- Powered Direct from Mains via Current Limiting Components or from DC Line

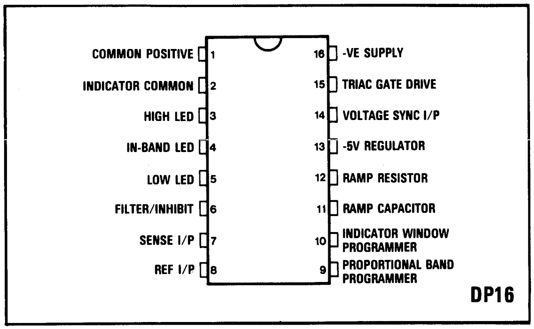


Fig.1 Pin connections - top view

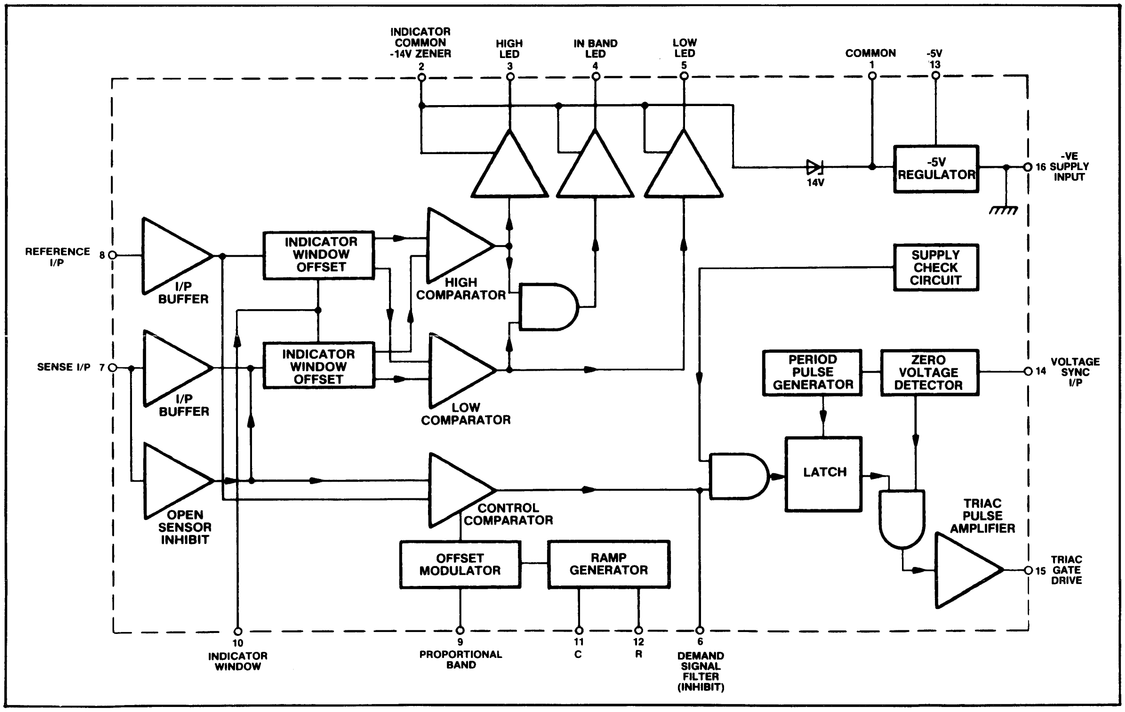


Fig.2 Block diagram

ELECTRICAL CHARACTERISTICS

Test conditions (unless otherwise stated):
$T_{amb} = 25°C$

Characteristic	Value			Units	Conditions
	Min.	Typ.	Max.		
CURRENT CONSUMPTION					
Pin 16					
IC operating current		3.5	5.5	mA	Not including triac gate or bridge supply current
VOLTAGE MONITOR					
Pin 16					
Voltage monitor enable level	-11		-9	V	
SHUNT VOLTAGE REGULATOR (V_{EE})					
Pin 2					
Regulating voltage	-13.5	-13.5	-15.5	V	
SERIES REGULATOR					
Pin 13					
Regulating voltage (V_{reg})	-5.35	-5	-4.65	V	1mA external load
External current			5	mA	
Regulation	120		120	mV	For 0-5mA load change
CONTROL COMPARATOR					
Pins 6,7,8					
Proportional control band	±20	±50	±80	mV	Pin 9 = -0.5
Proportional control band	±140	±200	±260	mV	Pin 9 = -2V
Pins 7,8					
Input bias current			2	μA	
Hysteresis		10		mV	
Pin 7					
OPEN SENSOR inhibit level	20		40	mV	With respect to V_{reg}
INDICATOR WINDOW COMPARATORS					
Pins 7,8					
Indicator window	±50	±100	±150	mV	Pin 10 = -0.5V
Indicator window	±300	±400	±500	mV	Pin 10 = -2V
Indicator window hysteresis	10		30	mV	
FILTER/INHIBIT INPUT					
Pin 6					
Output drive current	±10		±50	μA	
Inhibit trip level	-3.5		-2.6	V	
LED DRIVE CIRCUIT					
Pins 3,4,5					
LED drive current			40	mA	
High output voltage		6.4		V	Output current = 20mA Pin 2 connected to common
Output leakage current			10	μA	Output voltage = V_{EE}
TRIAC PULSE AMPLIFIER					
Pin 15					
Drive current	50	75	95	mA	Pin 15 = -3V
Leakage current			10	μA	Pin 15 = 0V
WINDOW PROGRAMMER					
Pin 10					
Input bias current			2	μA	Pin 10 = 0V
PROPORTIONAL BAND PROGRAMMER					
Pin 9					
Input bias current			2	μA	Pin 9 = 0V

ELECTRICAL CHARACTERISTICS (Continued)

Test conditions (unless otherwise stated):
$T_{amb} = 25°C$

Characteristic	Value			Units	Conditions
	Min.	Typ.	Max.		
RAMP GENERATOR					
Pin 11					
Ramp Capacitor charge current	-12		-6	μA	With 470k resistor from
Ramp capacitor discharge current	6		12	μA	Pin 12 to 0V
Upper ramp trip voltage	-1.0		-2.5	V	
Lower ramp trip voltage	-6.5		-5.5	V	
Pin 12					
Ramp programming current	5		50	μA	
VOLTAGE SYNCHRONISATION					
Pin 14					
Voltage synchronisation trip level (I_{sync})	±20	±25	±30	μA	
Period pulse trip level	35	50	75	μA	

ABSOLUTE MAXIMUM RATINGS

	Value	Units
ELECTRICAL		
-14V shunt regulator repetitive peak input current pin 2	100	mA
Non repetitive peak input current pin 2 ($t_p < 250\mu s$)	250	mA
Repetitive peak input current pins 3,4,5	100	mA
Non repetitive peak input current pins 3,4,5 ($t_p < 250\mu s$)	250	mA
Peak input current pin 14	±5	mA
-5V regulator current pin 13	10	mA
Supply voltage pin 16	-18	V
Voltage on pins 6,7,8,9,10	V_{reg}	V
Triac gate voltage pin 15	4	V
Ramp current pin 12	0.5	mA
THERMAL		
Operating ambient temperature	0 to 60	°C
Storage temperature	-55 to +125	°C

CIRCUIT DESCRIPTION

Power is supplied direct from the mains via current limiting components to a nominal 14V zener. An external capacitor maintains a smooth DC supply between mains cycles. The -14V supply is monitored by the supply check circuit which prevents unsuitable firing pulses being applied to the triac if the supply is less than that required to guarantee correct circuit operation.

A separate -5V series stabiliser provides internal biasing and a smooth external supply for the thermistor bridge and any ancillary control circuitry.

A differential input comparator compares the measured temperature with the set temperature to determine whether a power demand condition exists. A programmable triangular wave oscillator and modulator can vary the comparator offset such that a proportional control band and controlled switching rate are provided. Filtered and latched hysteresis feedback prevents switching jitter due to interference.

The power demand signal from the comparator is clocked into the latch by the period pulse which occurs once in each mains cycle, thus preventing halfwave firing of the triac.

The zero voltage detector generates a symmetrical pulse about the zero voltage points of the mains cycle. When gated by the latch output and amplified by the triac pulse amplifier the pulse provides the negative triac gate drive. By sensing the current in the voltage sync. pin (14) symmetrically about the zero voltage point, a firing pulse is produced which will maintain the triac in conduction throughout the entire mains cycle, thus minimising RF1. The width of the firing pulse is set by the external resistor in series with pin 14.

The device is capable of driving 3 LEDs to indicate a high, low or in-band temperature condition. The LEDs are connected in series with the device to reduce current consumption when power is provided direct from the mains via current limiting components, or in parallel when a DC supply is used.

The indicator window which determines the range of temperature over which the in-band LED is on, is programmed by the voltage applied to the indicator window programming pin (10). A similar input sets the width of proportional band for the control comparator. To minimise external component count, the indicator window and proportional band programming inputs (pins 10 and 9) may be connected to the same external voltage. Under these conditions the indicator window is twice the proportional control band.

DESIGN EXAMPLE (see application circuit Fig.3)

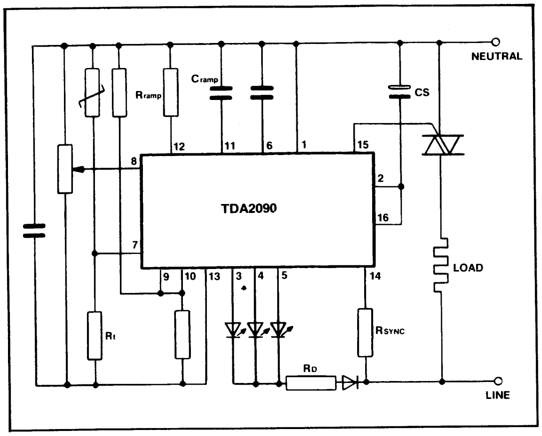


Fig.3 Basic AC mains supply application

RESISTOR R_{sync}

This resistor controls the width of the triac firing pulse (t_P) which is symmetrical about the mains zero crossing point as shown in Fig.4. To minimise RFI, the triac firing pulse width must be sufficient to ensure triac conduction throughout the entire mains cycle. As an example take a 1kW heating element operating from 240V AC mains using a triac with 50mA holding current (I_H).

Assuming a 5% manufacturing tolerance in the load resistance, the maximum value is given by:

$$\frac{V^2}{P} \times 1.05 = \frac{240^2}{1000} \times 1.05 = 60.48\Omega$$

The minimum mains voltage V_L required to ensure triac holding if the triac has a maximum on voltage V_t of 2V is given by:

$$V_L = I_H R_{Load} + V_t = 0.050 \times 60.48 + 2 = 5.024V$$

It is therefore necessary to ensure that the gate pulse extends beyond this point in the mains cycle in both positive and negative directions. The value of R_{sync} required to give a firing pulse of sufficient width is calculated from:

$$R_{sync} = \frac{V_L - V_{be}}{I_{sync}\ (min)} = \frac{5.024 - 0.7}{20 \times 10^{-6}} = 216.2K$$

In practice an R_{sync} value calculated for minimum triac firing pulse width in this way may sometimes produce an unacceptable high power dissipation in the sync resistor and a high peak current in the sync circuit. Since the contribution to total supply current by the triac firing pulse is small (about 0.86mA in this example) it may be advantageous to increase the value of R_{sync} somewhat to say 330K which reduces the power dissipation in R_{sync} to below 0.2W and increases the average triac firing pulse current to 1.2mA typical which is still acceptable.

AVERAGE GATE DRIVE CURRENT I_{15} (AV)

With the reservations expressed above on the value of R_{sync}, the average gate drive current should be kept to a minimum when the TDA2090 is being driven from the mains in order to reduce the power dissipated in the series dropper resistor R_D.

The maximum gate drive current is 100mA and this occurs twice each mains cycle, the average value being calculated from:

$$I_{15}(AV) = 2 \times t_P \times f \times 100mA$$

where t_P the gate pulse width is given by:

$$t_P = 2\left(\frac{V_{sync}^{*}}{V_m \times \sqrt{2} \times 2\pi f}\right)$$

*V_{sync} is equivalent to V_L but corrected for R_{sync} value used

Using the previous example with 330K + 10% R_{sync} and with the maximum I_{sync} value:

$$V_{sync} = (30 \times 10^{-6} \times 363K) + 0.7V = 11.59V$$

$$t_P = 2\left(\frac{11.59}{240 \times \sqrt{2} \times 2\pi f}\right) = 217\mu s$$

$$I_{15}(AV) = 2 \times 217 \times 10^{-6} \times 50 \times 100mA = 2.17mA\ (worst\ case)$$

If necessary the triac gate drive current can be reduced by connecting a resistor in series with Pin 15.

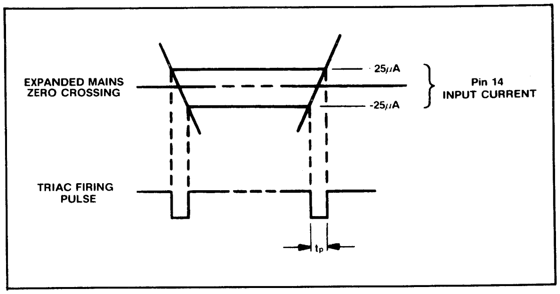


Fig.4 Firing pulse timing

MAINS DROPPING RESISTOR R_D

The value of R_D must be chosen to provide sufficient current for the IC plus the triac firing pulses and the bridge supply current on Pin 13.

Using the example above, the total DC supply current is given by:

$I_{total} = 5.5 + 2.17 + 1 = 8.67mA$, assuming 1mA for the bridge components.

The value of series dropper required can be calculated from:

$$R_D = \frac{\text{Peak Mains Voltage} - V_S max.}{\pi \times I_{total}}$$

where V_S max. is the zener voltage plus the voltage drop due to the LED and internal drive circuitry.

$$= \frac{240 \times 0.9 \times \sqrt{2} - 20}{\pi \times 8.67} = 10.5K\Omega$$

Specify R_D = 10K ± 5%

The power dissipated in R_D is

$$\frac{(\sqrt{2}V_{ac} - V_{cc})^2}{4R_D\ min.}\ \text{Watts}$$

$$\text{Maximum Power in } R_D = \frac{(\sqrt{2} \times 240 \times 1.1 - 14)^2}{4 \times 0.95 \times 10000} = 3.4W$$

MAINS SMOOTHING CAPACITOR C_s

The smoothing capacitor C_s should be chosen to give a supply ripple of less than 2V pk using the formula:

$$C_s = \frac{I_{total}}{V_{ripple} \times f_m} \times 10^3 = \frac{8.67}{2 \times 50} \times 10^3 = 86.7\mu F$$

Specify 100μF - 20 % + 100 %.

RAMP GENERATOR COMPONENTS C_{ramp} and R_{ramp}

These components determine the switching rate of the power applied to the load in the proportional control band. The rate of switching should be chosen to comply with EN50.006 and BS5406, 1976.

The capacitor value is given by:

$$\frac{It}{10} \times 10^6 \mu F$$

where t is the switching time in seconds and I is the capacitor charge current given by

$$I = \frac{V_{reg} - 0.7}{R_{ramp}}$$

The ramp current should be limited to between 5 and 50 micro-amps.

THERMISTOR BRIDGE CIRCUIT

The simple bridge circuit shown in Fig.3 uses a minimum number of components but has the disadvantage that the control range is effectively infinite. To limit the control range to that required it is usually necessary to introduce end-stop resistors R_a and R_b as shown in Fig.5.

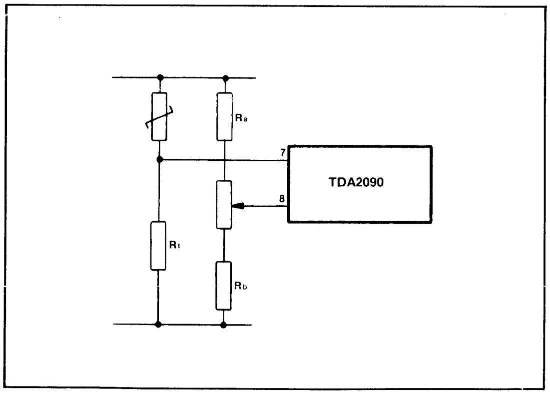


Fig.5

The resistor R_t in the thermistor arm is usually chosen for best linearity of the control potentiometer over the required temperature range.

When choosing thermistor bridge components, care must be taken to keep the bridge supply current to a reasonable level particularly at high temperatures when the thermistor resistance is low. If unsuitable thermistor and R_t values are selected, the voltage at pin 7 may fall below the open circuit sensor trip level at low temperatures preventing any power from reaching the load.

OPERATION FROM DC SUPPLY

Operation from DC is possible provided the voltage is higher than the maximum voltage monitor enable level and lower than the circuit maximum rating. Due to the design of the LED drive circuit, the LEDs must be driven in parallel as shown in Fig.7 R_L being used to limit the LED current.

ALTERNATIVE LED CONNECTIONS

In some applications 3 LEDs may not be required. In this case it is possible to combine several outputs onto one LED or to connect one or more outputs so that no LED indication is given. Fig.8 shows various methods of LED connection.

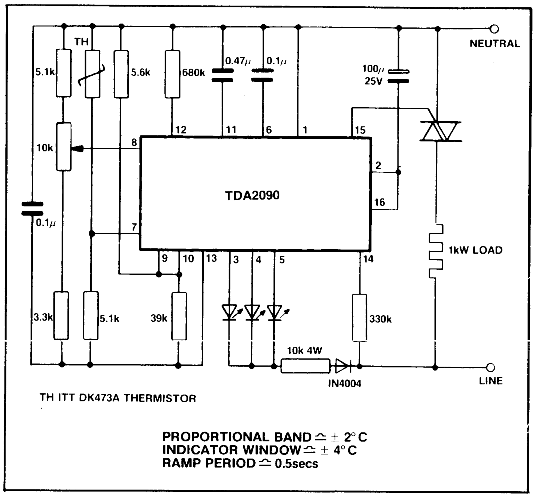


Fig.6 Application for 50-100° C temperature control

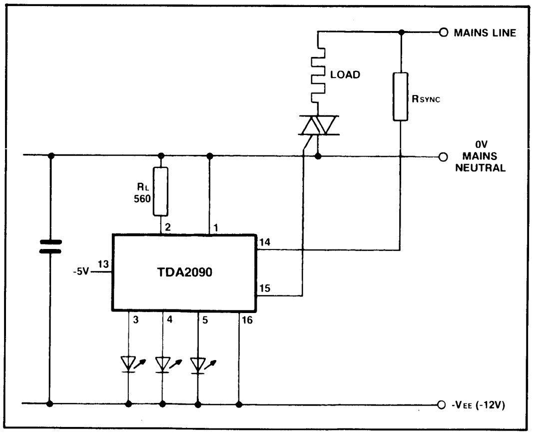


Fig.7 DC supply application

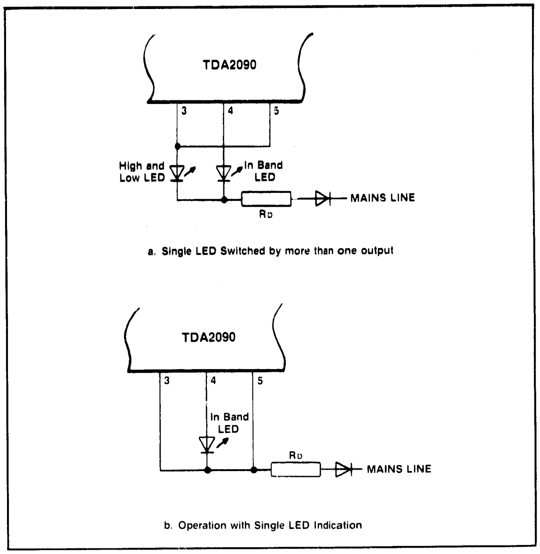
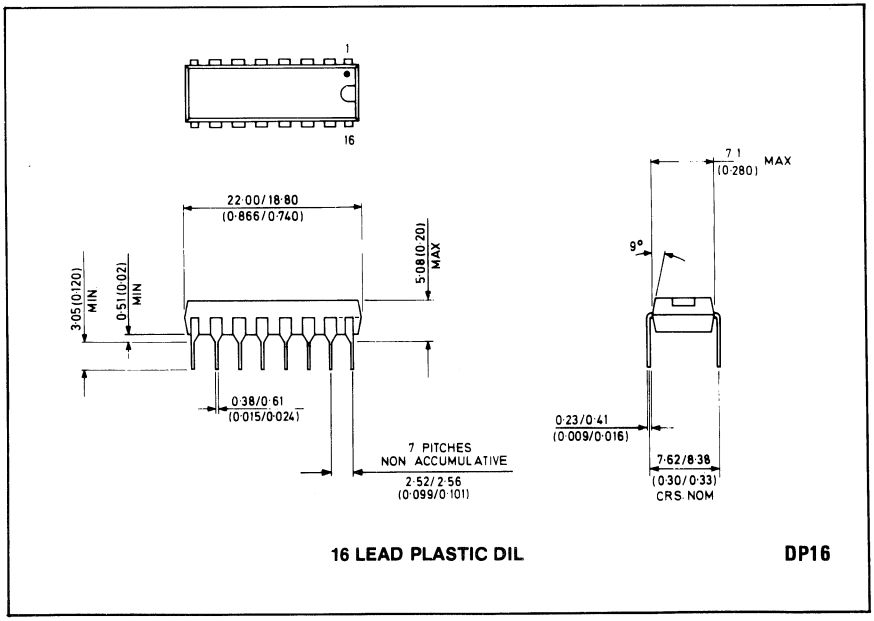


Fig.8 Alternative LED connections

PACKAGE DETAILS

Dimensions are shown thus: mm (in)



OPERATION WITHOUT PROPORTIONAL BAND

When only on/off control is required, a saving in external components may be made, as the ramp generator timing components are not necessary. In this case, Pin 9 is connected to common and Pins 11 and 12 connected to -5V.

The quality concept

In common with most semiconductor manufacturers, Plessey Semiconductors perform incoming piece parts check, in-line inspections and final electrical tests. However, quality cannot be inspected into a product; it is only by careful design and evaluation of materials, parts and processes - followed by strict control and ongoing assessment to ensure that design requirements are still being met - that quality products will be produced.

In line with this philosophy, all designs conform to standard layout rules (evolved with performance and reliability in mind), all processes are thoroughly evaluated before introduction and all new piece part designs and suppliers are investigated before authorisation for production use.

The same basic system of evaluation, appraisals and checks is used on all products up to and including device packing for shipment. It is only at this stage that extra operations are performed for certain customers in terms of lot qualification or release procedure.

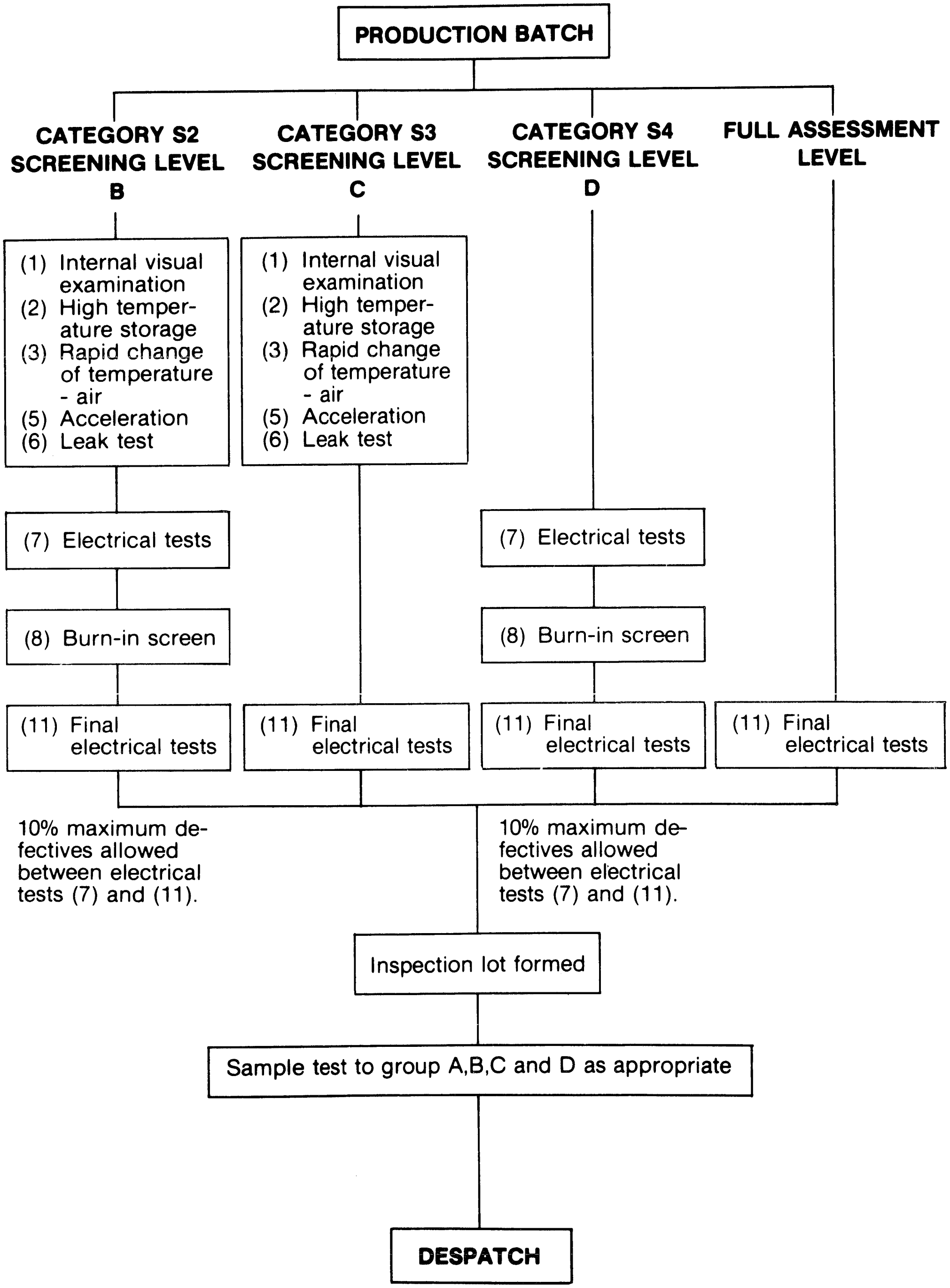
By working to common procedures for materials and processes for all types of customers advantages accrue to all users - the high reliability user gains the advantage of scale hence improving the confidence factor in the quality achieved whilst the large scale user gains the benefits associated with basic high reliability design concepts.

Plessey Semiconductors have the following factory approvals. **BS9300** and **BS9400** (BSI Approval No. 1053/M).

DEF-STAN 05-21 (Reg. No. 23H POD).

In addition a number of U.S., European and British customers manufacturing electronics for space have approved our facilities.

Screening to BS9400

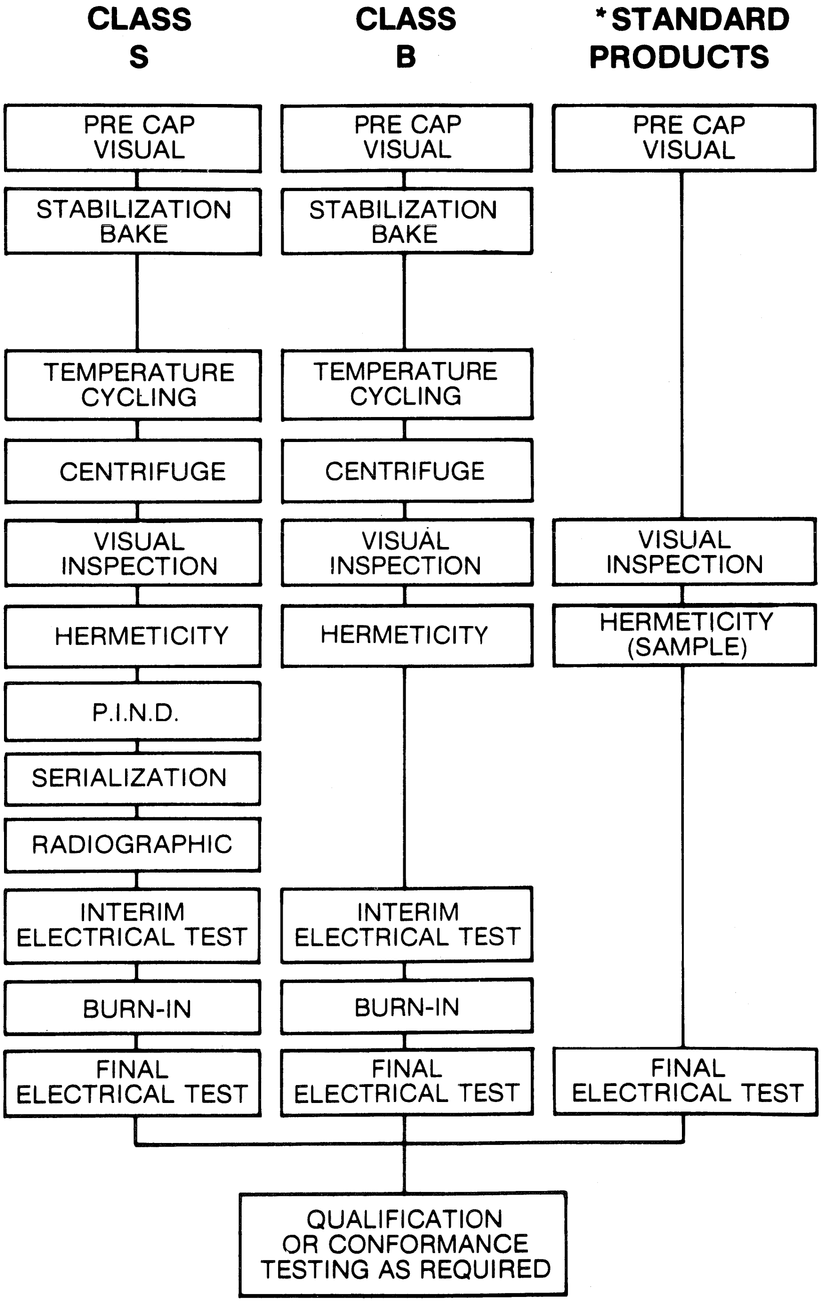


10% maximum defectives allowed between electrical tests (7) and (11).

10% maximum defectives allowed between electrical tests (7) and (11).

Plessey Hi-Rel screening

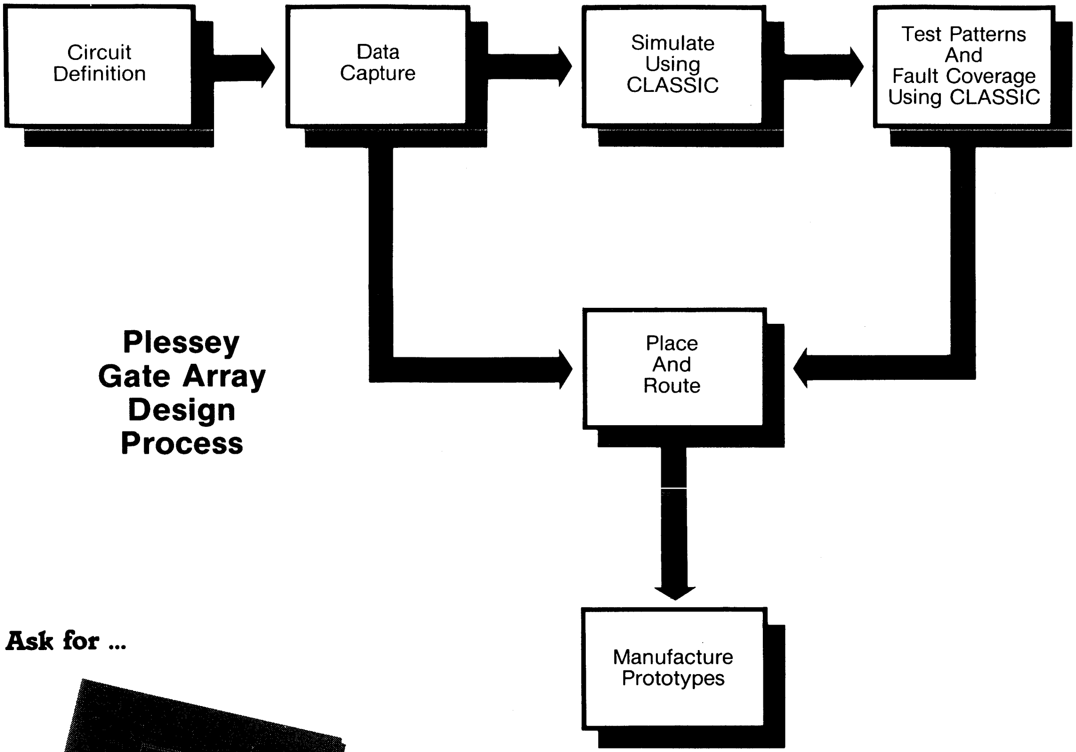
The following Screening Procedures are available from Plessey Semiconductors.



* Plessey Semiconductors reserve the right to change the Screening Procedure for Standard Products.

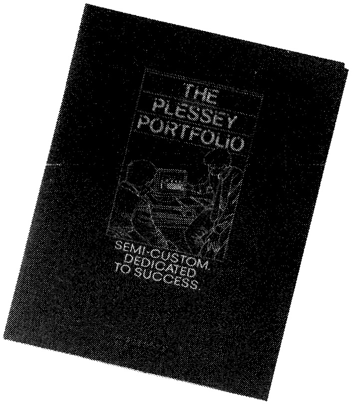
Semi-custom design

Plessey Semiconductors' advanced work in the Semi-Custom field enables us to offer our customers the opportunity to develop their own high performance circuits using our CLASSIC software. Among the many advantages are:
• CLASSIC is cost effective and user friendly • Prototypes in 6 weeks • Close coordination with customer throughout design and production process • State-of-the-art high performance produces • Up to 10044 gates available



Plessey Gate Array Design Process

Ask for ...



Microgate-C (Si-Gate CMOS)

CLA 3000 SERIES

- Double layer metallisation
- 4 micron channel length
- Product family:
  CLA31XX 840 Gates
  CLA33XX 1440 Gates
  CLA35XX 2400 Gates
  CLA37XX 4200 Gates
- 1.6ns typ. prop delay
- 20MHz system clock rate
- 40MHz toggle rate
- Fully auto-routed

CLA 5000 SERIES

- Double layer metallisation
- 2 micron channel length
- Product family:
  CLA51XX 640 Gates
  CLA52XX 1232 Gates
  CLA53XX 2016 Gates
  CLA54XX 3060 Gates
  CLA55XX 4408 Gates
  CLA56XX 5984 Gates
  CLA58XX 8856 Gates
  CLA59XX 10044 Gates
- 1.2ns typ. prop delay
- 40MHz system clock rate
- 100MHz toggle rate
- Fully auto-routed

Plessey Megacell™

Now there's a VLSI design system available that's perfect for solving your Application Specific Integrated Circuit (ASIC) problems. It's **PLESSEY MEGACELL** - a complete set of advanced computer-aided engineering and design tools coupled with an advanced CMOS process for implementing VLSI integrated circuits in the system design environment.

PLESSEY MEGACELL redefines semicustom integrated circuit design. It allows system engineers to design complex circuits with a high level of confidence of first time success in silicon - thanks to one of the best simulation facilities available in the world. This greatly reduces time to market, eliminating the many prototyping iterations that are all too common now in VLSI design.

PLESSEY MEGACELL is just about as close as you can get to achieving hand-crafted results short of full custom itself. System engineers can directly create their designs using the advanced layout and routing tools provided - without the aid of integrated circuit designers. So none of the system designers' application expertise is ever lost in transition, while chips of the smallest size and lowest production cost are regularly achieved.

Supporting the **PLESSEY MEGACELL** design capability is one of the most advanced CMOS processes available. It uses a 2-micron geometry capable of providing performance comparable with advanced Schottky TTL, with clock speeds to 40MHz and toggle rates of 100MHz achievable. And Plessey has established a 200,000 square foot dedicated processing facility to guarantee the manufacturing capacity required by even the most aggressive volume considerations.

PLESSEY MEGACELL is truly the gateway to the future - custom VLSI performance, with confidence of first time success and fast time to market. And it's going to stay that way - with Plessey's commitment to add future capabilities for high-speed ECL processes, 1 micron and submicron CMOS processes, and advanced analog capabilities.

Thermal design

The temperature of any semiconductor device has an important effect upon its long term reliability. For this reason, it is important to minimise the chip temperature; and in any case, the maximum junction temperature should not be exceeded.

Electrical power dissipated in any device is a source of heat. How quickly this heat can be dissipated is directly related to the rise in chip temperature: if the heat can only escape slowly, then the chip temperature will rise further than if the heat can escape quickly. To use an electrical analogy: energy from a constant voltage source can be drawn much faster by using a low resistance load than by using a high resistance load.

The thermal resistance to the flow of heat from the semiconductor junction to the ambient temperature air surrounding the package is made up of several elements. These are the thermal resistance of the junction-to-case, case-to-heatsink and heatsink-to-ambient interfaces. Of course, where no heatsink is used, the case-to-ambient thermal resistance is used.

These thermal resistances may be represented as

$\theta_{ja} = \theta_{jc} + \theta_{ch} + \theta_{ha}$
where θ_{ja} is thermal resistance junction-to-ambient °C/W
θ_{jc} is thermal resistance junction-to-case °C/W
θ_{ch} is thermal resistance case-to-heatsink °C/W
θ_{ha} is thermal resistance heatsink-to-ambient °C/W

The temperature of the junction is also dependent upon the amount of power dissipated in the device — so the greater the power, the greater the temperature.

Just as Ohm's Law is applied in an electrical circuit, a similar relationship is applicable to heatsinks.

$T_j = T_{amb} + P_D (\theta_{ja})$
T_j = junction temperature
T_{amb} = ambient temperature
P_D = dissipated power

From this equation, junction temperature may be calculated, as in the following examples.

Example 1

A device is to be used at an ambient temperature of +50° C. θ_{ja} for the DG14 package with a chip of approximately 1mm sq is 107° C/W. Assuming the datasheet for the device gives P_D = 330mW and T_j max = 175° C.

$$\begin{aligned} T_j &= T_{amb} + P_D\,\theta_{ja} \\ &= 50 + (0.33 \times 107) \\ &= 85.31°\text{C (typ.)} \end{aligned}$$

Where operation in a higher ambient temperature is necessary, the maximum junction temperature can easily be exceeded unless suitable measures are taken:

Example 2

A device with T_{amb} max. $= +175°C$ is to be used at an ambient temperature of $+150°C$. Again, $\theta_{ja} = 107°C/W$, $P_D = 330mW$ and T_j max. $= +175°C$.

$$\begin{aligned} T_j &= 150 + (0.33 \times 107) \\ &= +185.3°C \text{ (typ.)} \end{aligned}$$

This clearly exceeds the maximum permissible junction temperature and therefore some means of decreasing the junction-to-ambient thermal resistance is required.

As stated earlier, θ_{ja} is the sum of the individual thermal resistances; of these, θ_{jc} is fixed by the design of device and package and so only the case-to-ambient thermal resistance, θ_{ca}, can be reduced.

If θ_{ca}, and therefore θ_{ja}, is reduced by the use of a suitable heatsink, then the maximum T_{amb} can be increased:

Example 3

Assume that an IERC LIC14A2U dissipator and DC000080B retainer are used. This device is rated as providing a θ_{ja} of 55° C/W for the DG14 package. Using this heatsink with the device operated as in Example 2 would result in a junction temperature given by:

$$\begin{aligned} T_j &= 150 + (0.33 \times 55) \\ &= 168°C \end{aligned}$$

Nevertheless, it should be noted that these calculations are not necessarily exact. This is because factors such as θ_{jc} may vary from device type to device type, and the efficacy of the heatsink may vary according to the air movement in the equipment.

In addition, the assumption has been made that chip temperature and junction temperature are the same thing. This is not strictly so, as not only can hot spots occur on the chip, but the thermal conductivity of silicon is a variable with temperature, and thus the θ_{jc} is in fact a function of chip temperature. Nevertheless, the method outlined above is a practical method which will give adequate answers for the design of equipment.

It is possible to improve the dissipating capability of the package by the use of heat dissipating bars under the package, and various proprietary items exist for this purpose.

Under certain circumstances, forced air cooling can become necessary, and although the simple approach outlined above is useful, more factors must be taken into account.

Ordering information

Plessey Semiconductor integrated circuits are allocated type numbers which take the following general form

WW XXXX Y/ZZ

where **WW** is a two-letter code identifying the product group and/or technology, **XXXX** is a three or four numeral code uniquely specifying the particular device, **Y** is a single letter which denotes the precise electrical or thermal specification for certain devices and **ZZ** is a two-letter code defining the package style. Digits **WW**, **XXXX** and **Y** must always be used when ordering; digits **ZZ** need only be used where a device is offered in more than one package style.

The Pro-Electron standard is used for package codes wherever possible. The two letters of this code have the following meanings:

FIRST LETTER (indicates general shape)

A	Pin-Grid Array
C	Cylindrical
D	Dual-in-Line (DIL)
F	Flat Pack (leads on two sides)
G	Flat Pack (leads on four sides)
Q	Quad-in-Line

M	Miniature (for Small Outline)	Not yet designated by Pro-Electron
L	Leadless Chip Carrier	
H	Leaded Chip Carrier	

SECOND LETTER (indicates material)

C	Metal-Ceramic (Metal Sealed)
G	Glass-Ceramic (Glass Sealed)
M	Metal
P	Plastic
E	Epoxy

Please Note:

Leadless Chip Carriers

LC	Metal-Ceramic 3 Layer (Metal Sealed)
LG	Glass-Sealed Ceramic
LE	Epoxy-Sealed 1 Layer
LP	Plastic

Note: The above information refers generally to Plessey Semiconductors integrated circuit products and does not necessarily apply to all the devices contained in this handbook.

Plessey Semiconductors World Wide

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GREECE **Plessey Company Ltd.,** Hadjigianni Mexi 2, Athens. Tel: 21 724 3000 Tx: 219251.
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NEW ENGLAND REGION 132 Central St., 212, Foxboro, MA 02035. Tel: (617) 543-3855 Tlx: 316805.
SOUTHEAST REGION 499 Cranes Roost Blvd., Ste. 235, Altamonte Springs, FL 32701. Tel: (305) 339-6191 Tlx: 705185.
NORTHWEST REGION 4633 Old Ironsides Dr. 250, Santa Clara, CA 95054. Tel: (408) 986-8911 Twx: 62217370.
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	Eli Manis, Inc., P.O. Box 605, Cote St. Luc., Montreal, Quebec H4V 2Z2. Tel: (514) 484-2923 Tlx: 05-25134 MTL.
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