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.

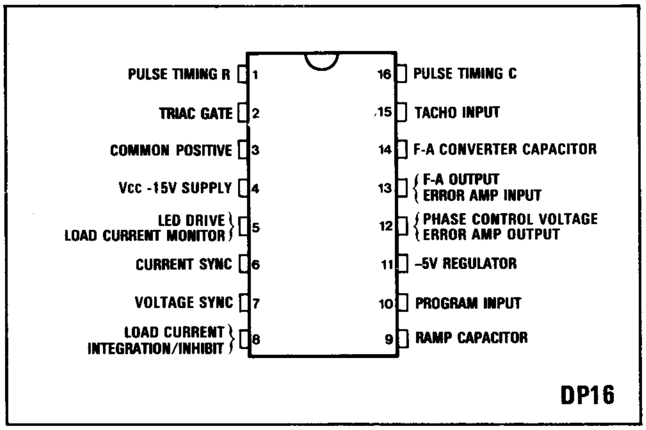


Fig.1 Pin connections - top view

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

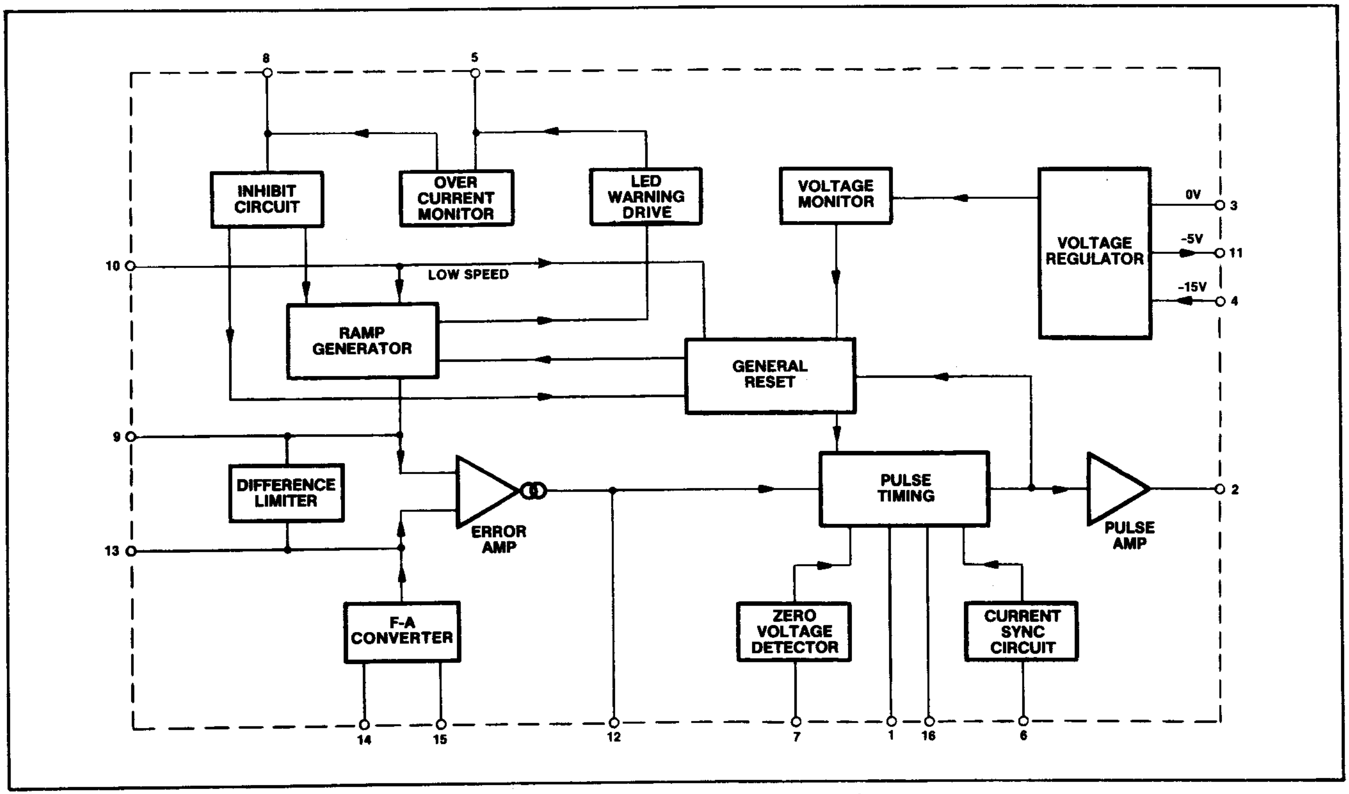


Fig.1A Block diagram of TDA2085A

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.

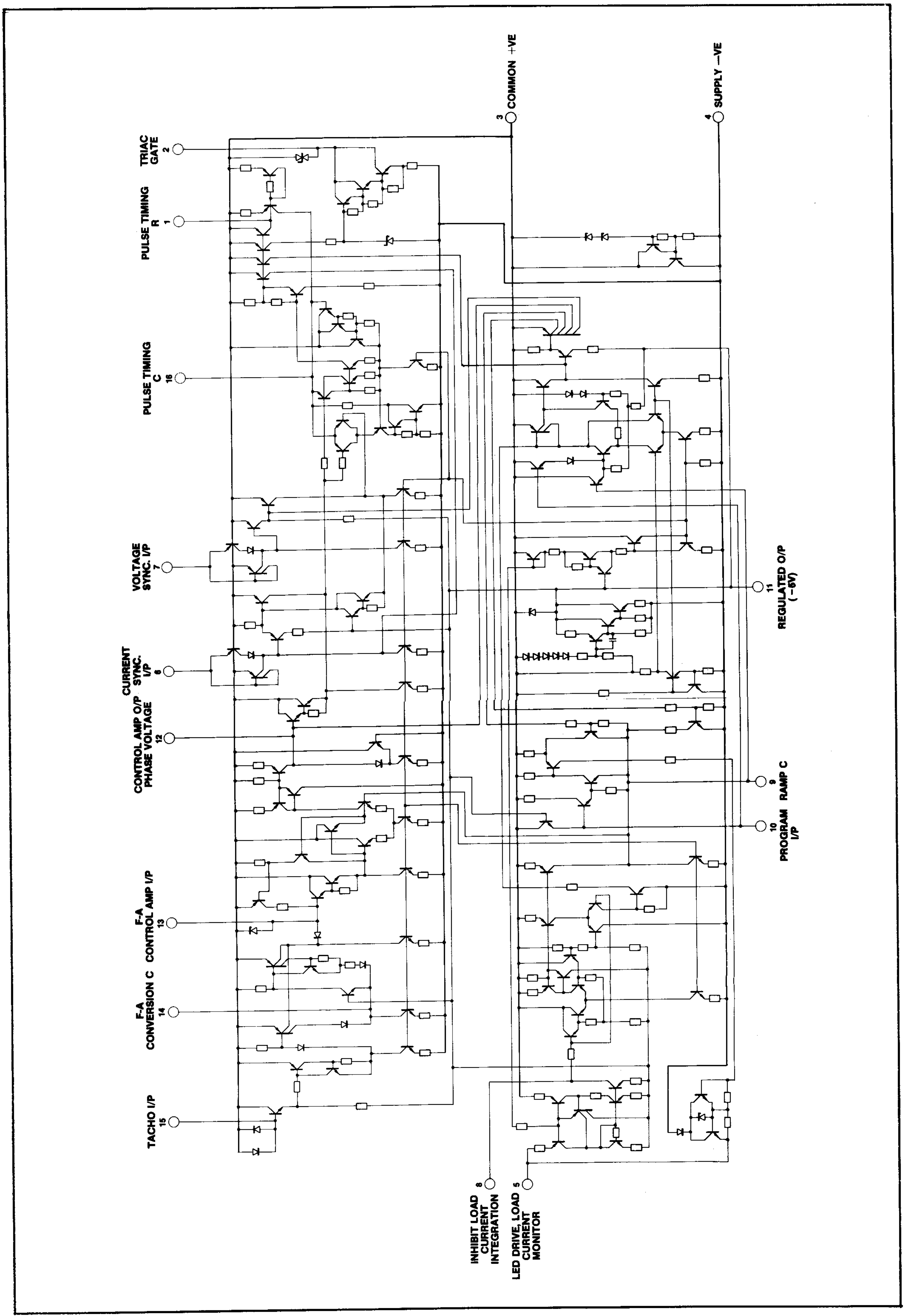


Fig.2 TDA2085A circuit diagram

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			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 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 (I_{SYNC}) pin 6	±3	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	±10	mA
THERMAL		
Operating ambient temperature	0 to +85	°C
Storage temperature	-55 to +125	°C

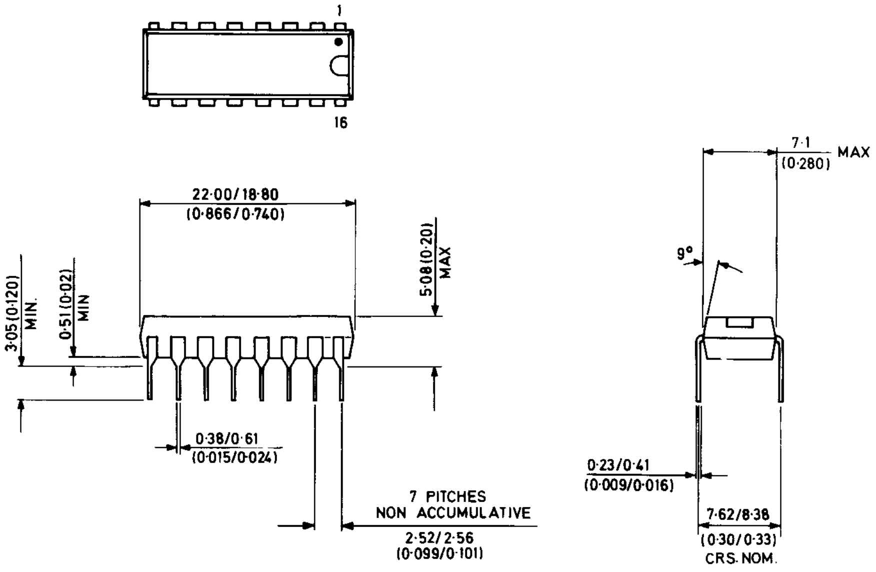
TACHO INPUT DRIVE

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 **DP16**

This devices will also be offered in an SO16 package - contact your local sales office for information.

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.

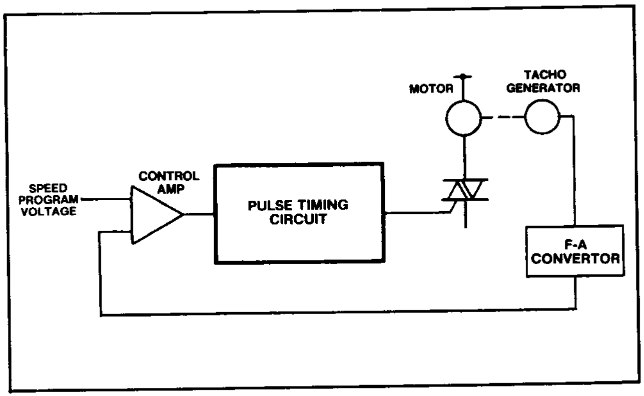


Fig.3 Basic closed loop control system

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

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

where K is the conversion factor given by

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

and ft is the tacho frequency given by

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

using 1 and 3 above

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

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

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

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

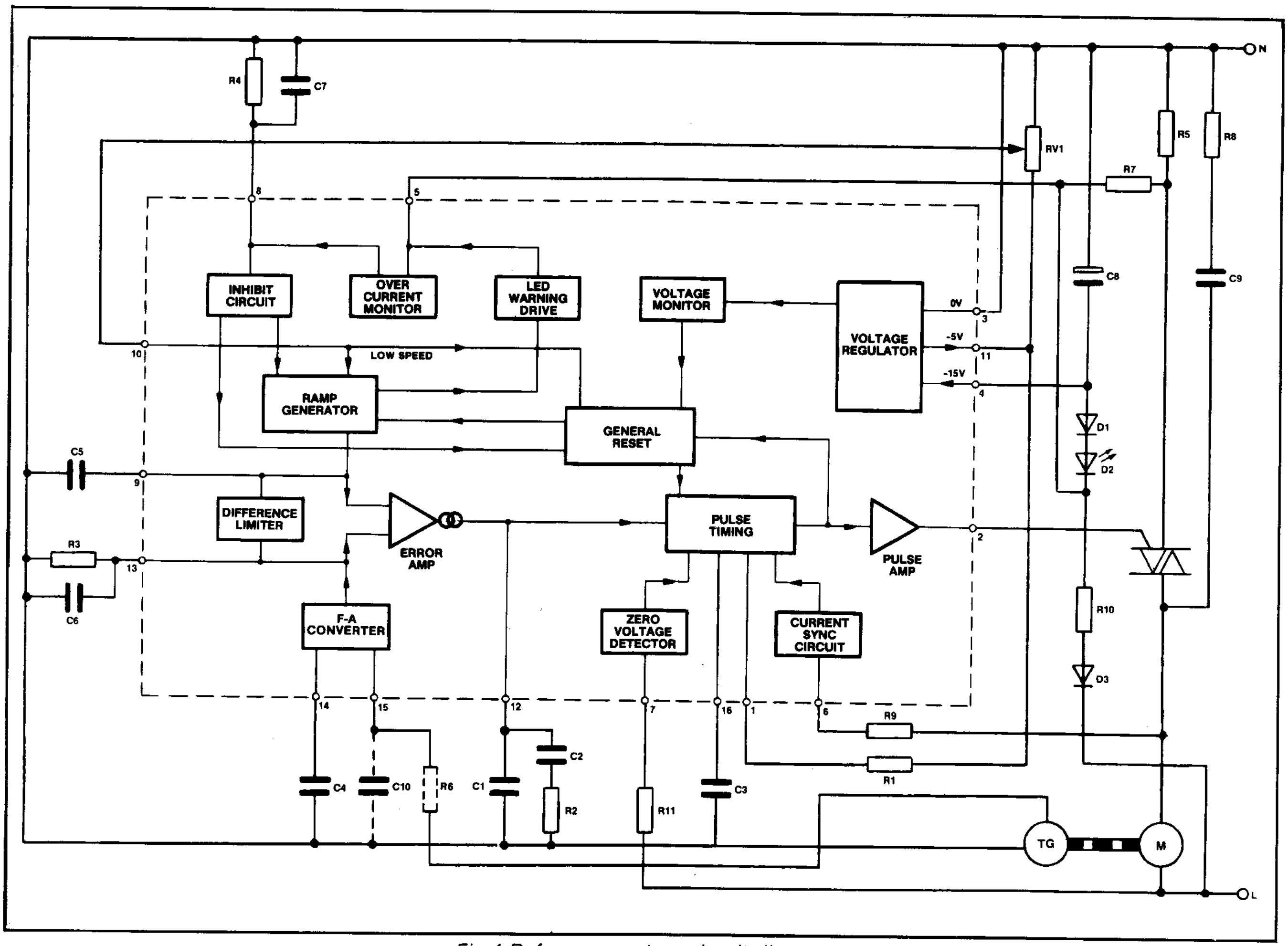


Fig.4 Reference system circuit diagram

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

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

and the acceleration time $= \dfrac{2.5V}{3.0V/s} = 0.83$ 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

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

Dynamic ramp voltage on pin 16

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

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

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

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

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

For load current inhibit

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

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.

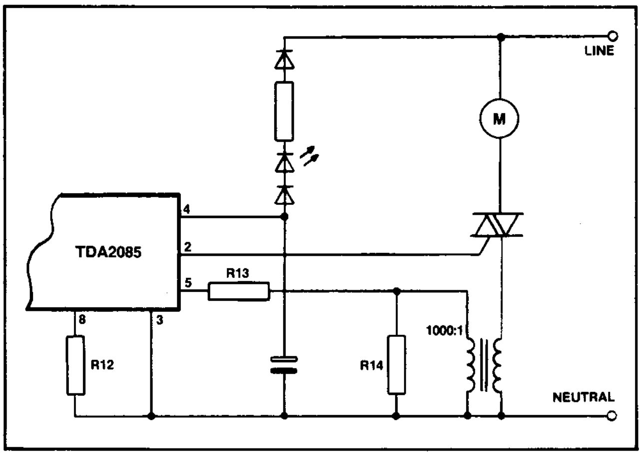


Fig.5 Current transformer application

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

For load current limit

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

For load current inhibit

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

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

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

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.

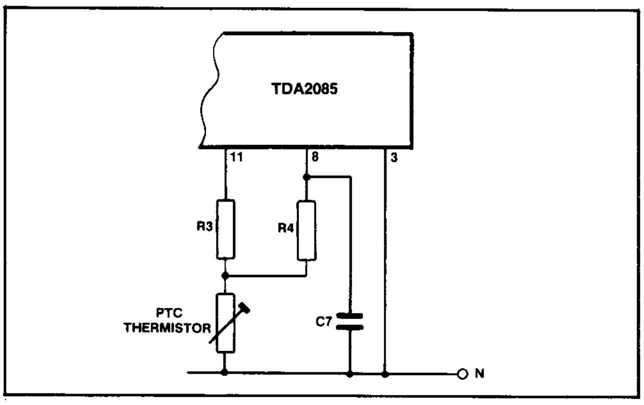


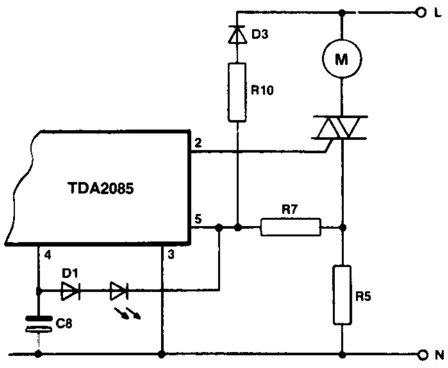
Fig.6 Over-temperature shut-down

AC SUPPLY CIRCUITS

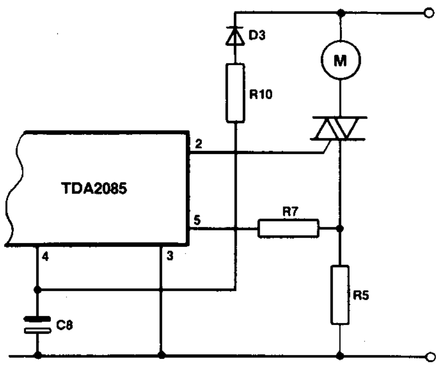
The TDA2085 circuit has been designed for very low power consumption, this parameter being particularly important when operating from mains voltages via a dropper resistor.

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

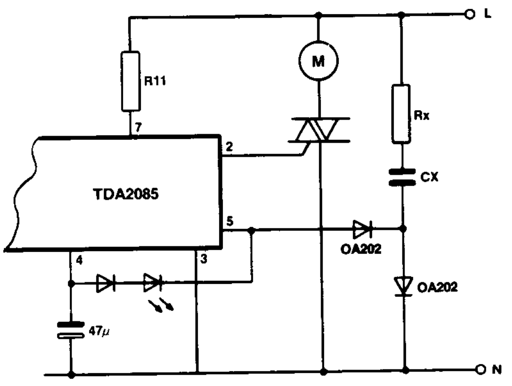
$$C8 = \frac{Is}{Vcr \times fm} \times 10^3 \mu F \quad ..13$$

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

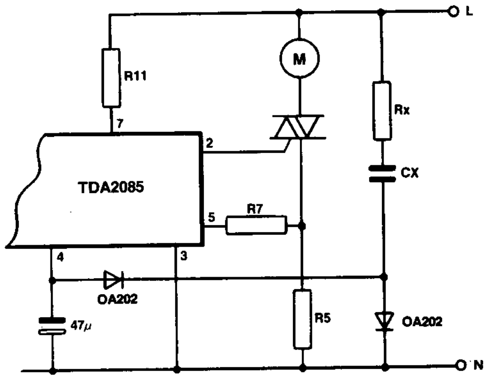
$$Pdr = \frac{(\sqrt{2}\ Vac - Vcc)^2}{4R10}\ W \quad ...15$$

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.



(a) With LED drive



(b) With current overload

Fig.8 Reactive feed circuits

The value of Cx can be calculated from

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

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

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

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.

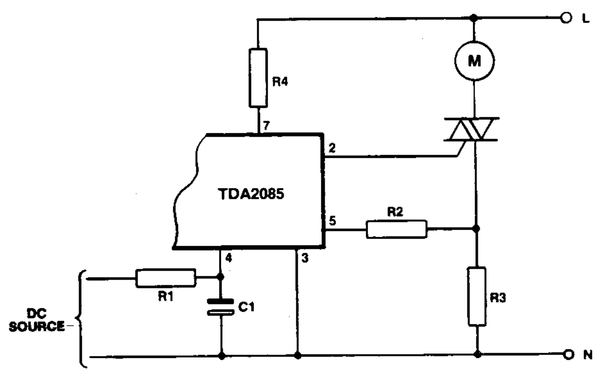


Fig.9 Operation from unstabilised DC

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.

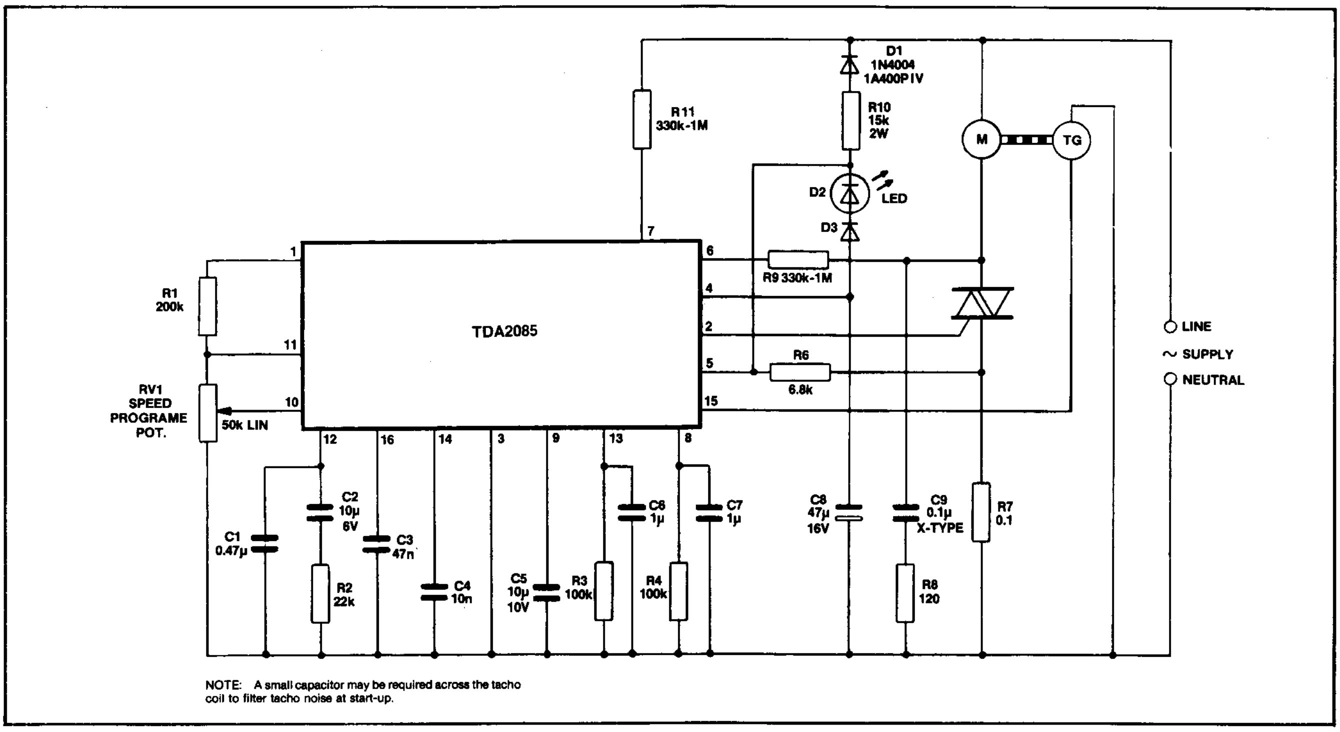
CURRENT FOLDBACK

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.

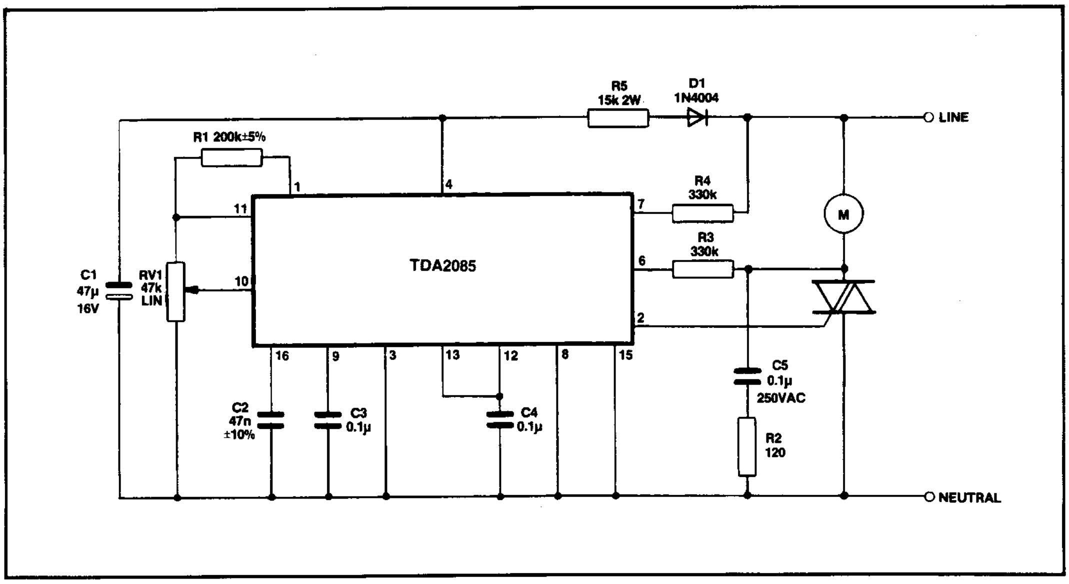


Fig.11 Open loop application, 240V

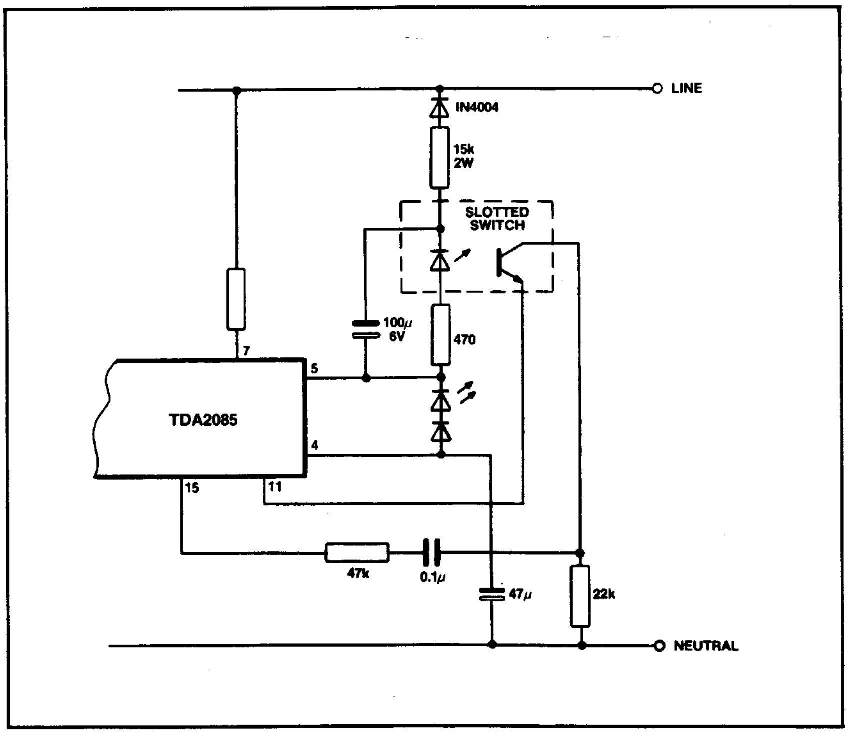


Fig.12 Optical feedback application

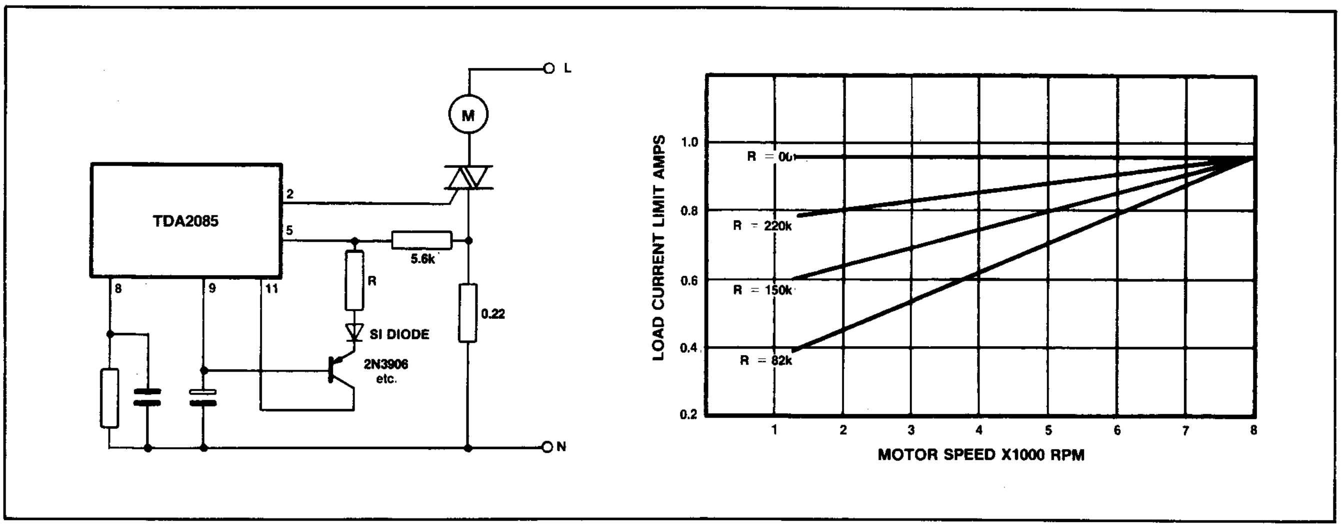


Fig.13 Current limit foldback, method 1

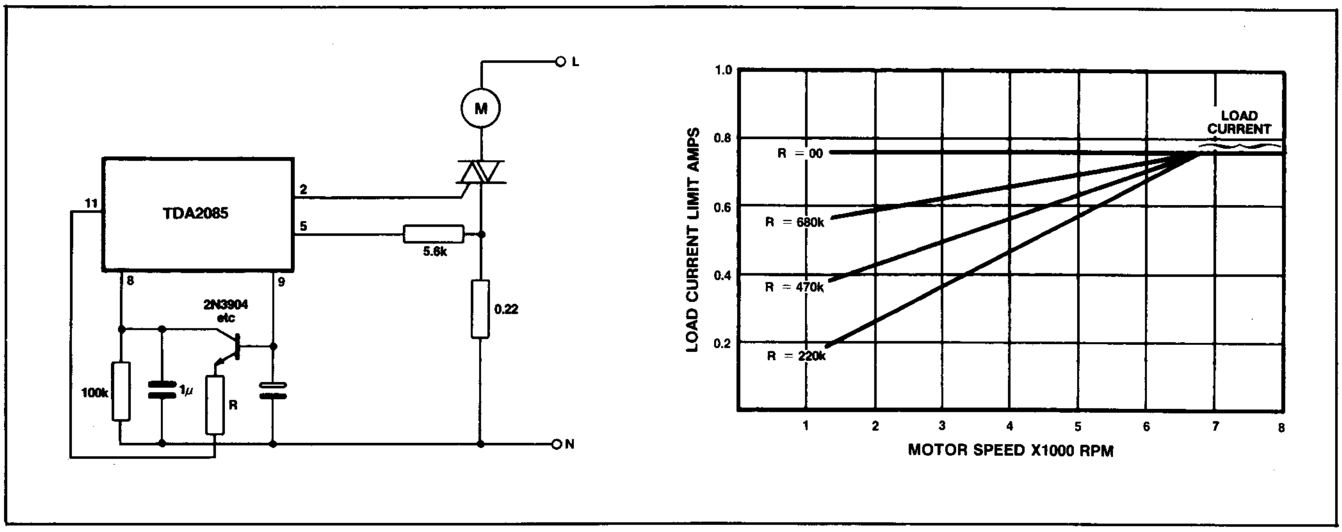


Fig.14 Current limit foldback, method 2

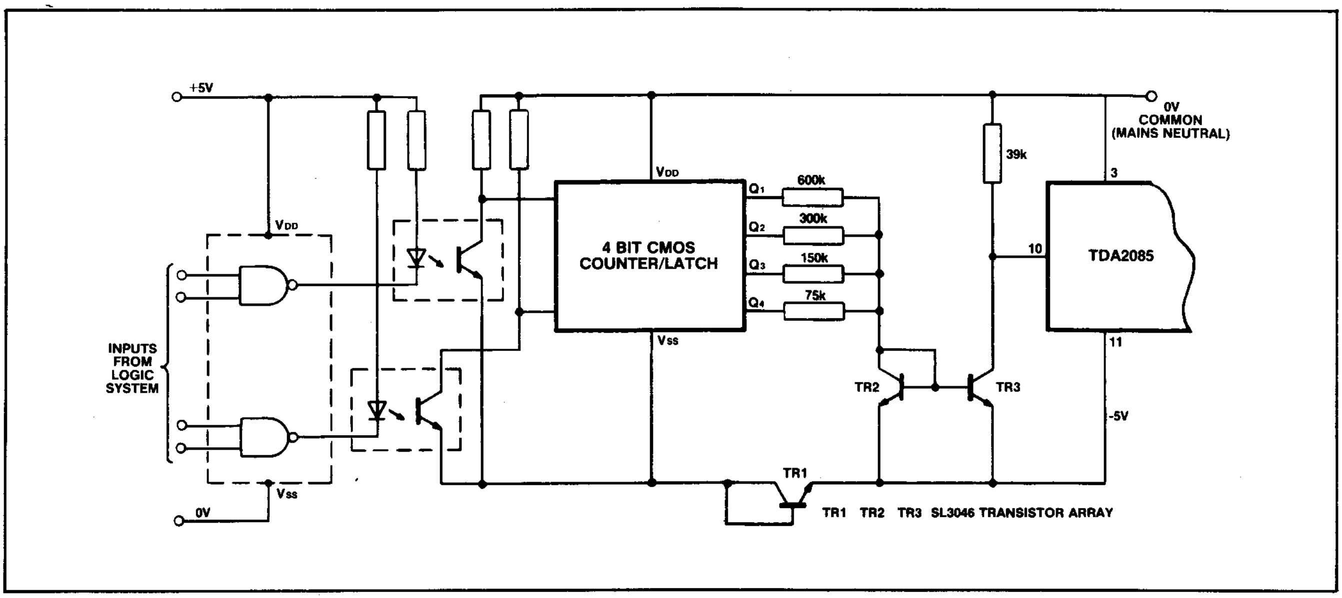


Fig.15 Interface to digital system

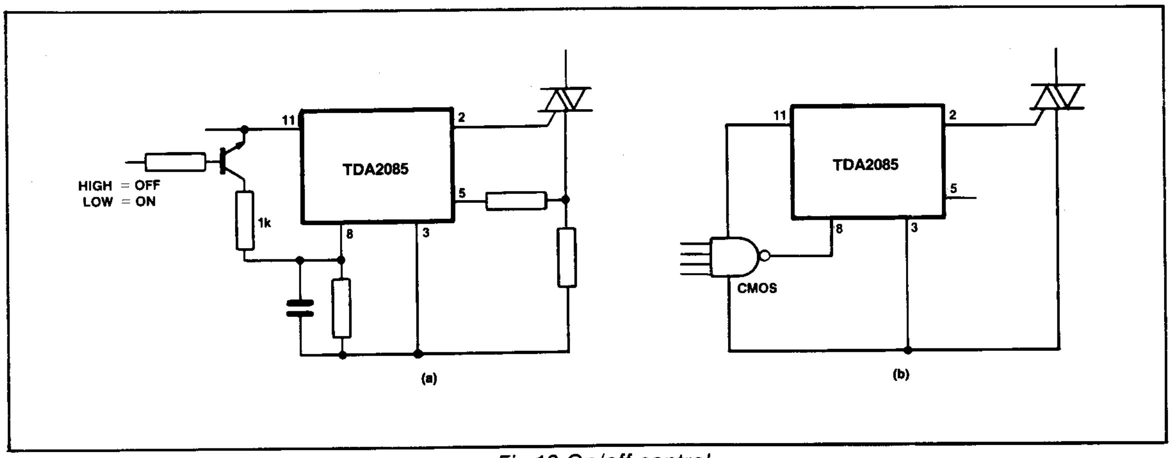


Fig.16 On/off control

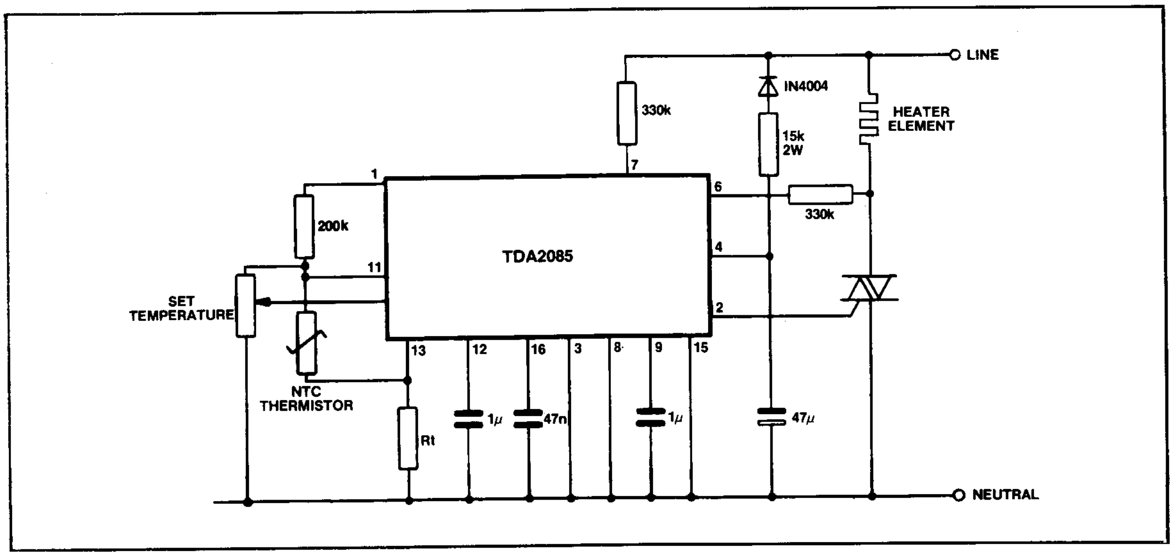


Fig.17 Temperature control application

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.

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 as 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.

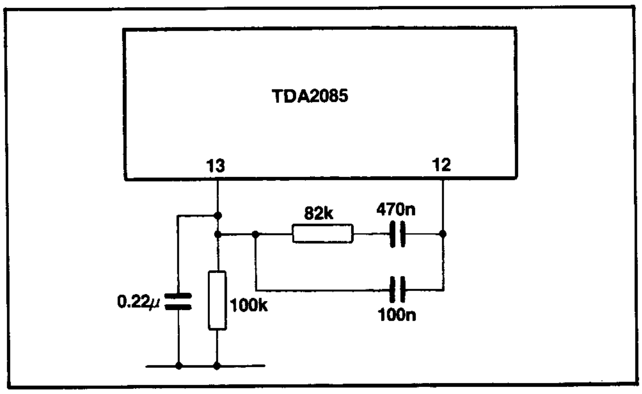


Fig.18