Triac Phase Angle Controller

Description

The LD1185 generates controlled triac triggering pulses and allows tachless speed stabilization of universal motors by an integrated positive feedback function. Typical applications are power hand tools, vacuum cleaners, mixers, light dimmer and other small appliances.

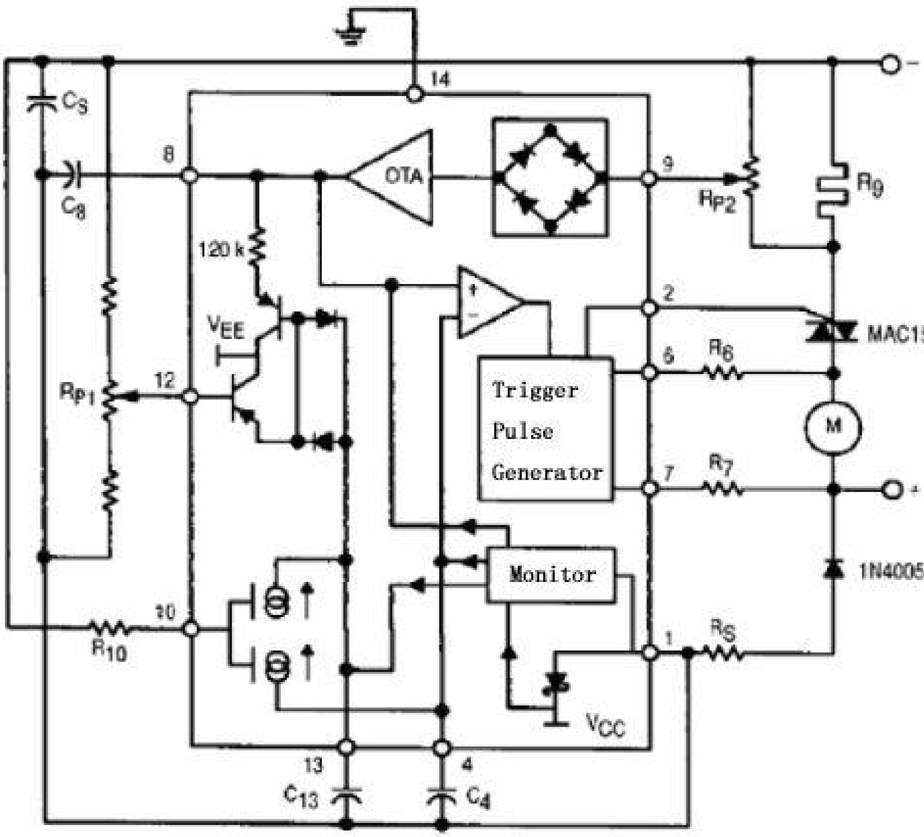
Features

- Supply Power Obtained from AC Line
- Can be used with 220V/50Hz or 110V/60Hz
- Low Count/Cost External Components
- Optimum Triac Rring (2nd and 3rd Quadrants)
- Repetitive Trigger Pulses when Triac Current is Interrupted by Motor Brush Bounce
- Triac Current Sensing to Allow Inductive Loads
- Programmable Soft-Start
- Power Failure Detection and General Circuit Reset
- Low Power Consumption: 6.0mA

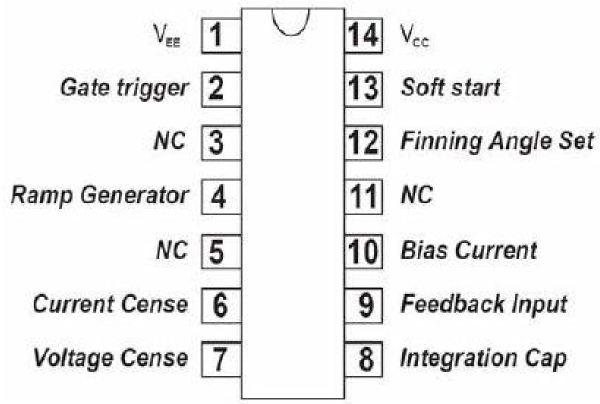
Ordering Information

Package	Remarks
SOP14	Tubed, Reeled, Pb-free
DIP14	Tubed, Pb-free

Figure 1. Representative Block Diagram



Pin Connections



Pin Function Description

Pin	Function	Description
1	V_{EE}	This pin is the negative supply for the chip and is clamped at -8.6V by an internal zener.
2	Gate Trigger Pulse	This pin supplies – 1.0 V triac trigger pulse at twice the line frequency.
3	NC	Not connected.
4	Ramp Generator	The value of the capacitor at this pin determines the slope of the ramp.
5	NC	Not connected.
6	Current Sense	This pin senses if the triac is on, and if so, will disable the gate trigger pulse.
7	Voltage Sense	The internal timing of the chip is set by the frequency of the voltage at this pin.
8	Integration Capacitor	This pin is the output of the feedback and the variation in voltage is averaged out by the capacitor.
9	Feedback Input	The change in load current is detected by the change in voltage across R9.
10	Current Program	The bias current for the circuit is determined by the resistor value at this pin.
11	NC	Not connected.
12	Phase Angle Set	The voltage at this pin sets the no-load firing angle.
13	Soft-Start	The firing angle is slowly increased from 180℃ to the set value of Pin 12.
14	V_{CC}	Ground

Maximum Ratings (Voltages are referenced to Pin 14, ground)

Rating		Symbol	Value	Unit
Maximum Voltage Range per Listed Pin				
Pin3, 5, 11 (not connected)		V_{PIN}	-20 to +20	V
Pins4, 8, 13			-VCC to 0	
Pin 2			-3.0 to +3.0	
Maximum Positive Voltage	Pin12		0	
(No minimum value allowed)	Pin1		0.5	
Maximum Current per Listed Pin				
Pin 1		I_{PIN}	±20	mA
Pin 6, 7			±2.0	
Pin 9			±0.5	
Pin 10			±300	μA
Pin12			-500	
Maximum temperature range				
Maximum Power Dissipation (T_A=25℃)		P_D	250	mW
Maximum Thermal Resistance; Junction-to-Ambient		$R_{\theta JA}$	100	℃/W
Operating Ambient Temperature Range		T_A	0 to + 70	℃
Storage Temperature Range		T_{stg}	-55 to <+ 125	℃

Electrical Characteristics

(T_A=25℃, Voltages are referenced to ground/Pin 14, unless otherwise noted)

Characteristics	Symbol	Min	Typ	Max	Unit
Power Supply					
Zener Regulated Voltage（V_{Pin1}），I_{Pin1}= 2.0 mA	$-V_{CC}$	-9.6	-8.6	-7.6	V
Circuit Current Consumption（I_{Pin1}），V_{Pin1}=-6. 0V，I_{Pin2}=0A	$-I_{CC}$	-2.0	-1.0		mA
Monitoring Enable Supply Voltage（V_{EN}）	V_{Pin1EN}	V_{CC}+0.2		V_{CC}+0.5	V
Monitoring Disable Supply Voltage（V_{DIS}）	$V_{Pin1DIS}$	V_{EN}+0.12		V_{EN}+0.3	V
Phase Set					
Control Voltage Static Offset V_{Pin3}-V_{Pin12}	V_{off}	1.2		2.0	V
Pin 12 Input Bias Current	I_{Pin12}	-200		0	nA
V_{Pin4}-V_{Pin12} Residual Offset			180		mV
Soft-Start Capacitor Charging Current R_{Pin10}=100 kΩ， V_{Pin13} from $-V_{CC}$ to -3.0V	I_{Pin13}	-17	-14	-11	μA

Electrical Characteristics (Continue)

(T_A=25℃, Voltages are referenced to ground/Pin 14, unless otherwise noted)

Characteristics	Symbol	Min	Typ	Max	Unit
Sawtooth Generator					
Sawtooth Capacitor Discharge Current R10=100 kΩ, V_{Pin4} from -2.0 to -6.0V	I_{Pin4}	67	70	73	μA
Capacitor Charging Current	I_{Pin4}	-10		-1.5	mA
Sawtooth "High" Voltage (V_{Pin4})	V_{HTH}	-2.5	-1.6	-1.0	V
Sawtooth Minimum "Low" Voltage (V_{Pin4})	V_{LTH}		-7.1		V
Positive Feedback					
Pin 9 Input Bias Current, V_{Pin9}=0	I_{Pin9}		2×I_{Pin10}		
Programming Pin Voltage Related to Pin1	V_{Pin10}	1.0	1.25	1.5	V
Transfer Function Gain V_{Pin8}/ V_{Pin9}					
R_{10}=100 kΩ, V_{Pin9}=50 mV	A		75		
R_{10}=270 kΩ, V_{Pin9}=50 mV	A		36		
Pin 8 Output Internal Impedance	Z_{Pin8}		120		kΩ
Trigger Pulse Generator					
Output Current (Sink) V_{Pin2}=0V	I_{Pin2}	60		80	mA
Output Leakage Current V_{Pin2}=+2.0V				4.0	μA
Output Pulse Width, C_4=47nF, R_{10}=270kΩ	t_P		55		μs
Output Pulse Repetition Period	t		420		μs
Current Synchronization Threshold Levels I_{Pin6}, I_{Pin7}	I_{sync}	-40		+40	μA

Introduction

The LD1185 generates trigger pulses (Pin 2) for triac control of power into an AC load. The triac trigger pulse is determined by generating a ramp voltage (Pin 4) synchronized to twice the AC line frequency and compared to an external set voltage (Pin 12) representing the conduction angle. Gate pulses are negative (sink current) and thus the triac is driven into its most effective quadrants (Q2 to Q3).

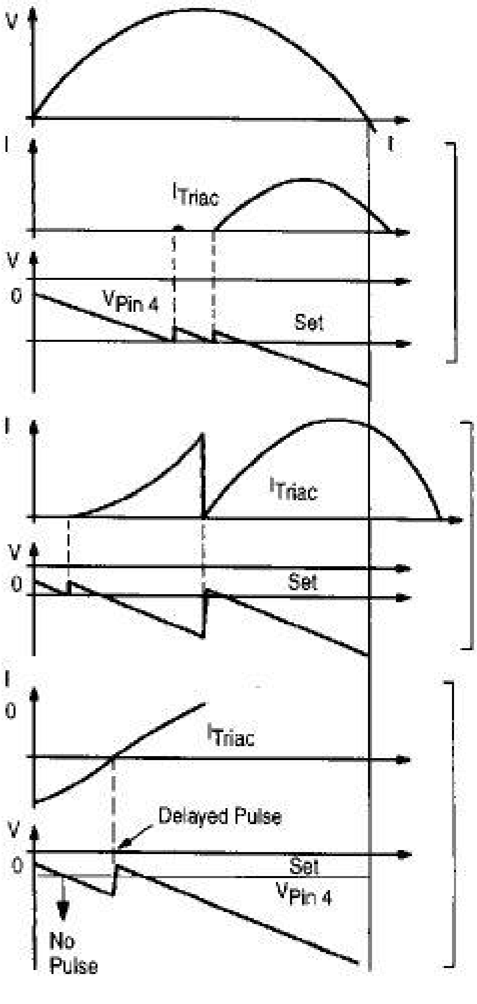
If the load is a Universal motor (the speed of which decreases as torque increases), the LD1185 allows to increase the conduction angle proportionally to the motor current, sensed (Pin 9) by a low value resistor in series with the load.

DC Power Supply

DC power is directly derived from the AC line through a 2.0 W resistor, half-wave rectifier and filtering capacitor circuit. The VEE voltage is internally regulated by an integrated zener. Referenced to ground (Pin 14), the power supply voltage is - 8.6 V. The LD1185 internal consumption is 6.0 mA.

Trigger Pulse Generator

It delivers a 60 mA minimum sink current pulse (Pin 2) through an internally short circuit protected output. Pulse width is roughly proportional to R10 × C4 and is repeated every 420 µs if triac fails to latch or is switched off by brush bounce. With inductive loads, the current lags in respect to the voltage. Pin 6 delays the triggering pulse up to the moment the triac is off, in order to prevent erratic power control (see Figure 2).



The triac failed to latch at the first pulse. Successive pulses are generated up to the moment latching occurs.

The triac turned off due to brush bounce, a new pulse is immediately delivered.

Approaching full conduction, a pulse would occur when the triac still carries current; the pulse is delaye until the triac turns off.

Figure2. Multipulse Generation Delayed Pulse

Ramp Generator

A constant current sink discharges capacitor C4 producing a negative voltage ramp synchronized with the main line. Pin 4 voltage is reset to -1.6V at every AC line zero crossing (see Figure 3) and ramps down to -7.1V. The constant current sink is externally programmable by R10 using the equation below.

$$I_4 = I_{10} \pm 5\% \qquad I_{10} = \frac{|V_{EE} + 1.25|}{R_{10}}$$

Main Comparator

Its role is to determine the trigger pulse which occurs when the ramp voltage equals the phase angle set voltage at Pin 12. Fixed phase angle set voltage values lead to a constant TRIAC conduction angle unless positive current feedback (Pin 9) is connected or the Soft-Start capacitor (Pin 13) is not charged.

Soft-Start

The LD1185 allows the user to avoid any abrupt inrush of current into the load. This provides protection for fragile loads, light bulbs or tubes. Another advantage is that the AC line disturbance is minimized.

The conduction angle is established from zero to the set value at Pin 12 according to a voltage ramp generated by a constant current delivered to C13. The value of current I13 can be expressed by the following equation: $I_{13} = 0.2 \times I_{10} \pm 10\%$

The voltage ramp lasts as long as V13 is lower than the set voltage V12. Upon reset, V13 is forced to VEE as shown in Figure 4. If the load is a universal motor, it will not turn until a minimum conduction angle is achieved to overcome friction. The time the voltage ramp requires to reach its threshold value is considered deadtime, and can be eliminated by an appropriate series resistor Pin 13. The voltage drop developed by I13 thus resistor causes the conduction angle to immediately reach the threshold value and have the Soft-Start function without dead time (see Figure 5).

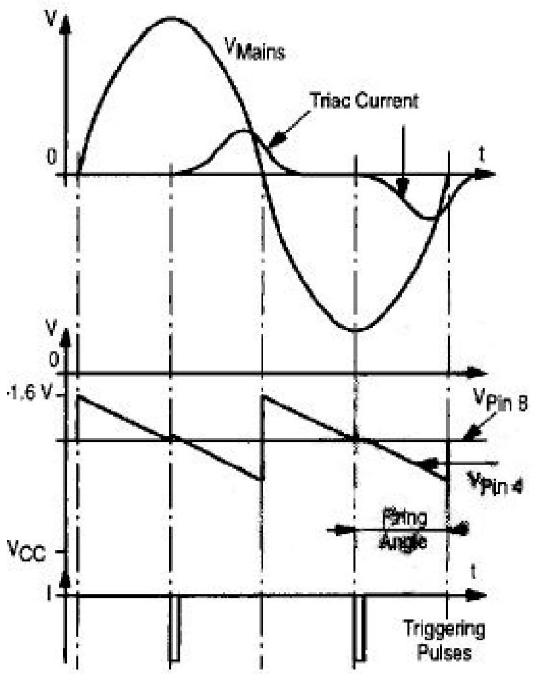


Figure 3. Triggering Pulse Timing

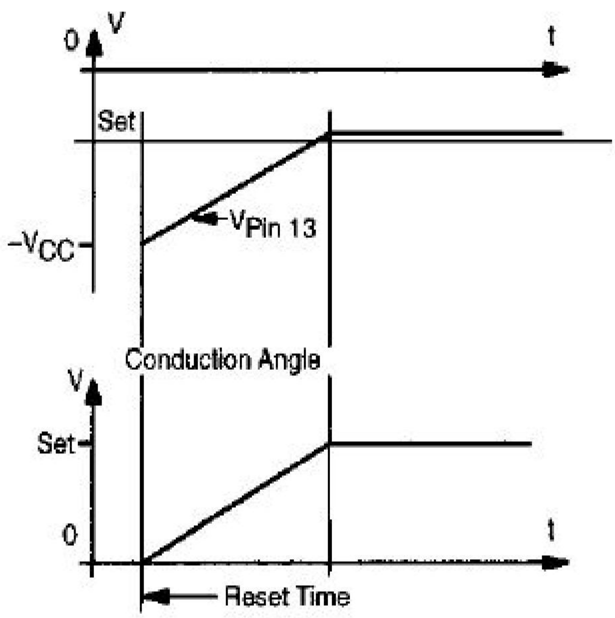


Figure 4. Soft-Start

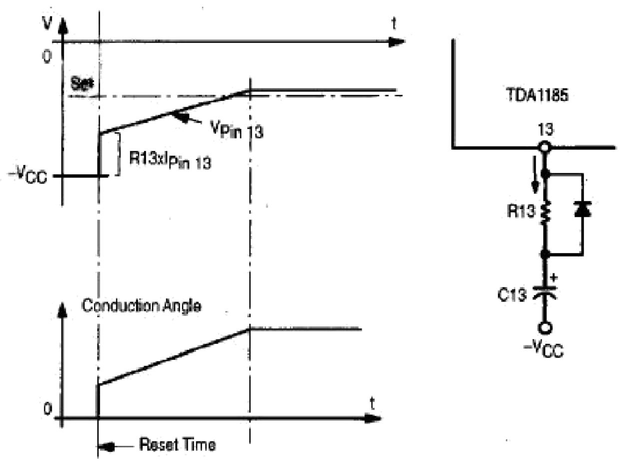


Figure 5. Soft-Start without Deadtime

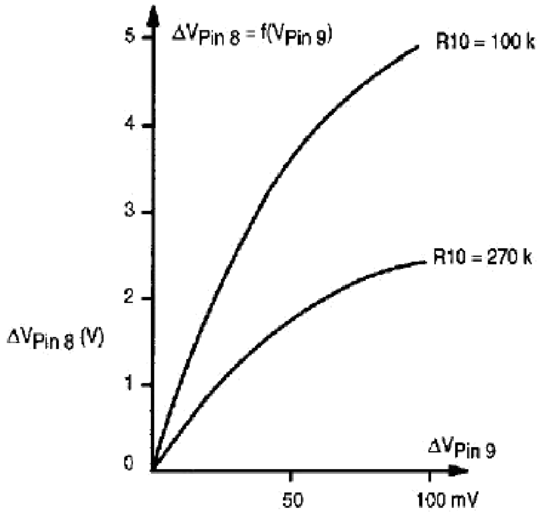


Figure 6. Transfer Function

Positive Current Feedback

The Universal motor speed drops as load increases. To maintain the speed, the triac conduction angle must be increased. For this purpose, Pin 9 senses the motor current as a voltage developed in a low value resistor, R9, amplifies, rectifies and adds it internally to the set voltage at Pin 12. Any voltage variation at the output of the feedback, Pin 8, is smoothed out by capacitor C8. The transfer function, ΔV8 = f(ΔV9), is shown in Figure 6.

The gain in the linear region is dependent on R10. The voltage transferred to Pin 8 is proportional to the current RMS value, as motor current is not far from a sine wave. This averaging effect is shown in Figure 7.

With large amplitude signals at Pin 9, the change in voltage at Pin 8 reaches a maximum value. This saturation effect limits the maximum conduction angle increase. This effect is illustrated in Figure 8 where the total Pin 8 voltage can be written as follows: $V_8 = V_{12} + f(|V_9|, R_{10}) + 1.25$

The effect of the feedback is illustrated in Figure 9.

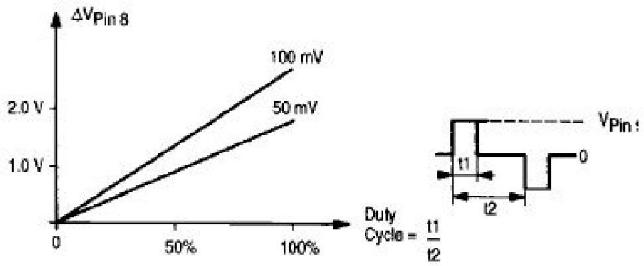


Figure 7. Averaging Effect of Transfer Function

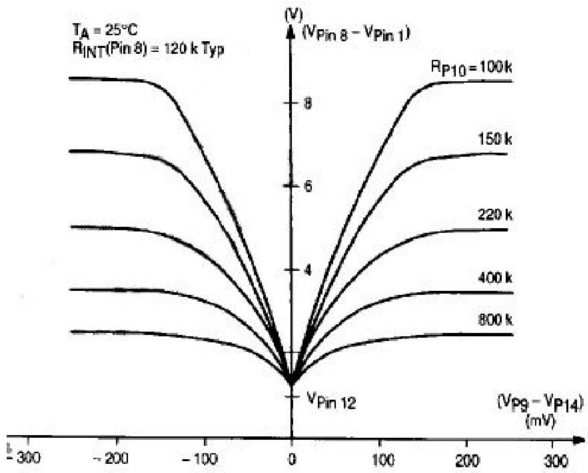


Figure 8. Transfer Function (Pin 8/Pin 9)

Monitoring

A central logic block performs the ENABLE/DISABLE function of the IC with respect to power supply voltage. Under DISABLE conditions, Pin 4, 8, 12 and 13 are forced to appropriate voltages to prepare for the next reset. Refer to the block diagram in Figure 10.

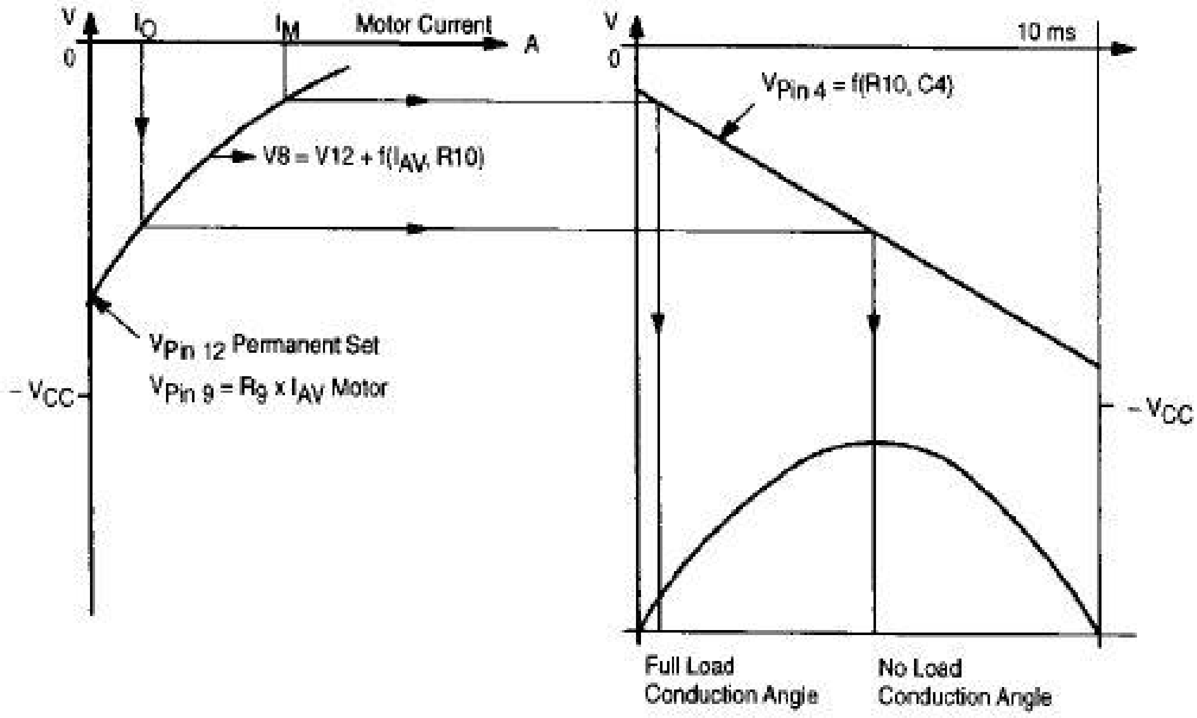


Figure 9. Positive Feedback Effect (Offset voltages have been neglected)

Application Considerations

Component Selection

To regulate the speed of a universal motor, it is necessary to determine how much gain in the feedback is needed. A change in motor current (due to load increase) the conduction angle to change by the appropriate amount to keep the speed constant. This entails through trial and error, choosing an appropriate resistor value for R10, since the gain of the feedback is determined by value of R10 as shown in Figure 8. Once R10 is picked, C4 can be calculated from the following equation: $C_4 \approx \frac{.672}{f_{line} \times R_{10}}$

(where fline is the line frequency)

Capacitor C8 is an integration cap used to smooth out the voltage at Pin 8. The value should be large enough to accomplish this task yet not too large to slow the response of the system.

Capacitor C13 determines how fast the conduction angle reaches the set value programmed at Pin 12. To achieve a desired delay, the value for C13 can be calculated by the following equation:

$$C_{13} \approx \frac{8 \times t_d}{|8.6 - V_{12}| \times R_{10}}$$

The remaining component values have experimentally been determined and are constant, regardless of application. The following table lists typical values for 110 V application.

Component	Value	Unit
R_S	10/2.0W	kΩ
R_{P1}	100	kΩ
R_{P2}	100	Ω
R_6	330/0.5W	kΩ
R_7	330/0.5W	
R_9	0.05/5.0W	Ω
R_{10}	100	kΩ
C_4	0.1	μF
C_8	0.22	μF
C_{13}	10	μF

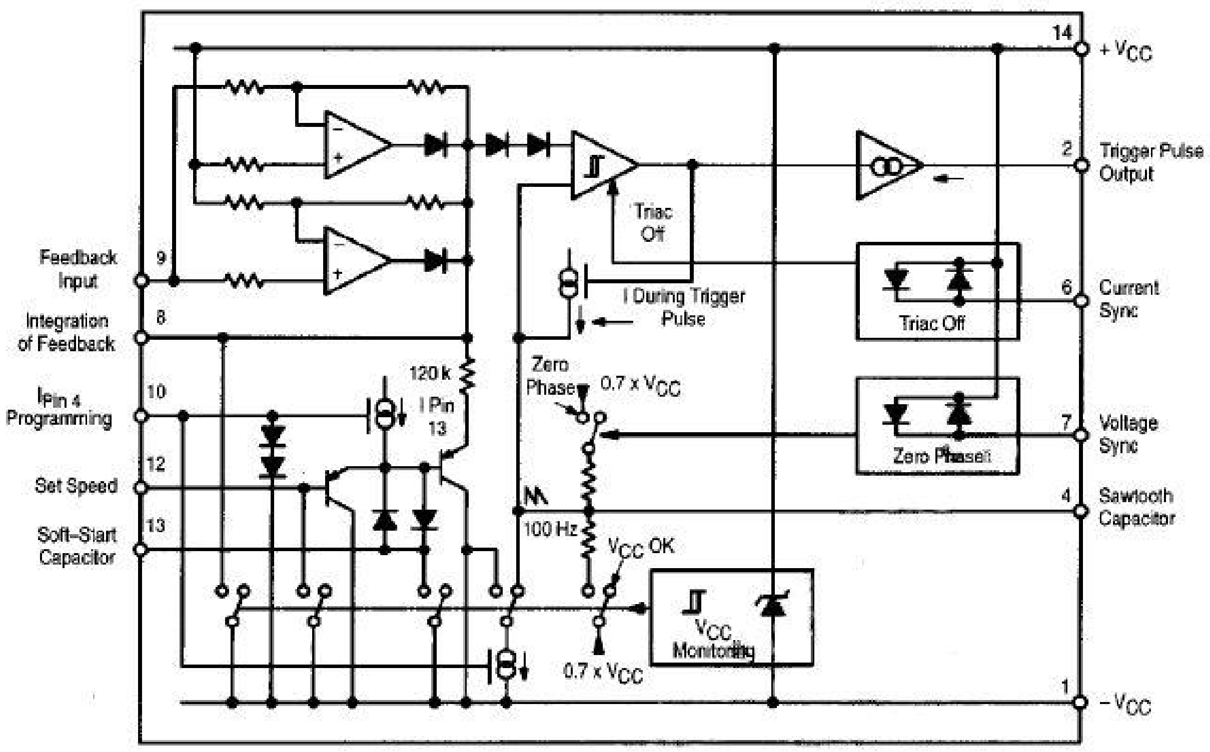


Figure 10. Internal Block Diagram

Using an oscilloscope, it should be verified that the ramp generator is ramping down from -1.6 to -7.1 V. The slope of the ramp can be changed by C4 and the DC level of the waveform can be adjusted by R7.

Pin 9 has a low internal impedance and requires RP2 to adjust the feedback level. Pin 8 must always be connected to VEE through a filtering capacitor. For values of R10 less than 100 kΩ, the circuit becomes sensitive and could become unstable. Figures 11 and 12 show typical waveforms. As shown, the increase in motor current has resulted in the firing angle to decrease. This translates to an increase in the average power delivered to the load.

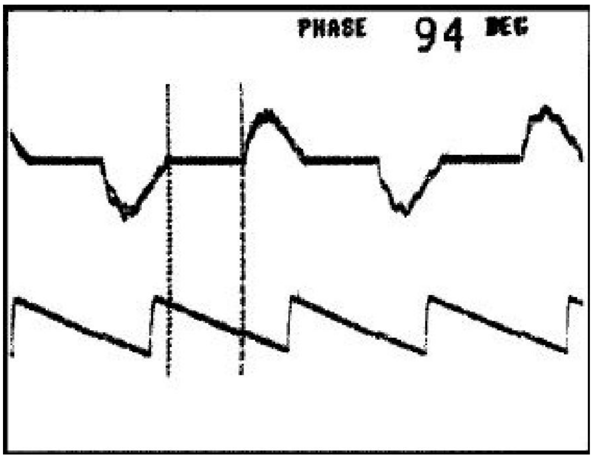


Figure 11. No Load Applied

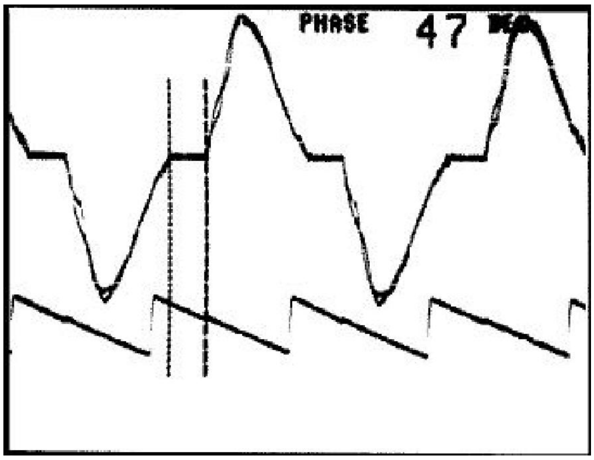


Figure 12. Load Applied

Temperature Effects

The LD1185 has a very efficient internal temperature compensation. If the current feedback is not connected, the RMS power delivered to the load is stabilized within ± 0.2% over a temperature range of 20 to 70° C. The feedback introduces, in the same temperature range, a drift of 250 mV on the voltage of Pin 8; this slight increase in conduction angle may be successfully used to compensate a motor ohmic resistance increase with temperature.

Main Line Voltage Compensation

As the conduction angle is independent of main line voltage, any change in the latter induces a power variation to the load. A resistor connected to the rectifier anode and to Pin 12 with a capacitor to VEE will introduce a decrease in voltage at Pin 12 as the line voltage is increasing. the values of the RC network can experimentally be determined.

Firing Angle Dynamics

With purely resistive loads, the effective RMS applied voltage to the load is directly to the load is directly proportional to the firin g angle (Figure 13).

With inductive loads, since the current lags with respect to voltage, 100% power corresponds to a firing angle which is less than 180°.

Application Ideas

Soft-Star

The Soft-Start feature of the LD1185 in itself opens the door to a lot of interesting applications.

For example, the LD1185 can be used to bring up fragile loads slowly. Expensive and sensitive tubes can be turned on slowly, thus eliminating the inrush of current that could lead to burn out. In this application, RP1 is replaced with a resistor divider such that the voltage at Pin 12 results in a conduction angle of 180°. Pin 9 should be grounded, since the feedback portion of the LD1185 is not necessary (see Figure 14). The time to achieve full conduction is found by the equation below: $\Delta t = 8.71 \times R_{10} \times C_{13}$

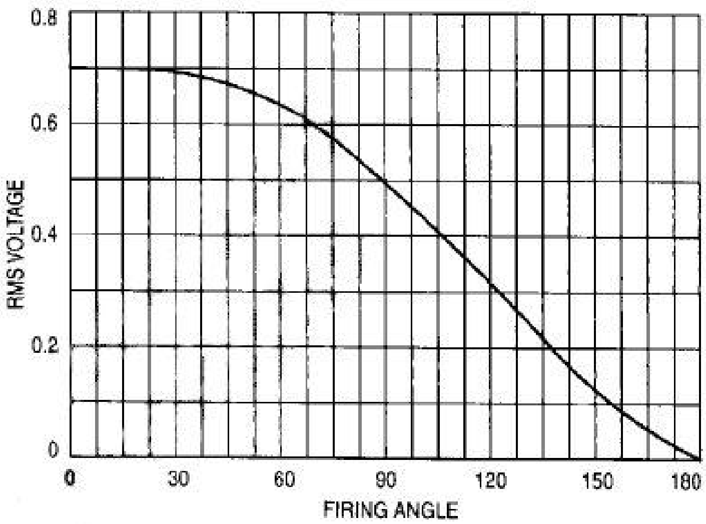


Figure 13. RMS Voltage versus Firing Angle

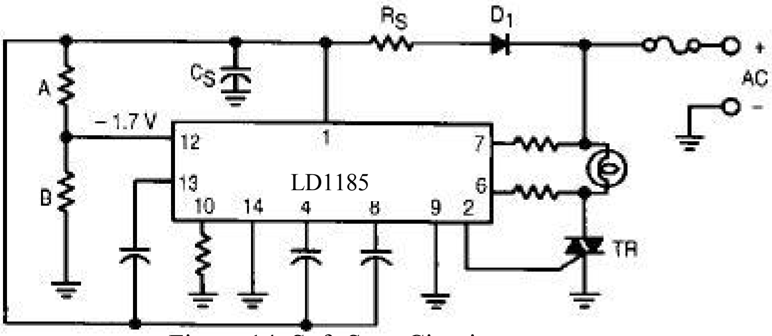


Figure 14. Soft-Start Circui

R_S=10kΩ/2W C_4=44nF

R_6=470kΩ/0.5W C_{13}=10uF

R_7=470kΩ/0.5W C_S=100uF

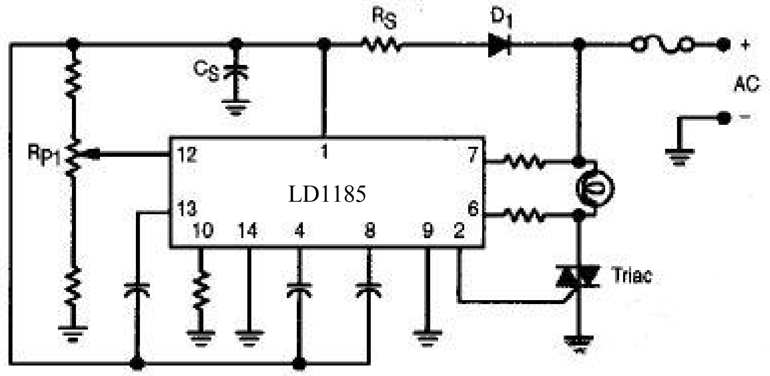
R_{10}=200kΩ $R_{12A}=4\times R_{12B}$

Turn-off Tim=$8.71\times R_{10}\times C_{13}$

Light Dimmer

With practically no modification the LD1185 can be used in a light dimmer application. All that is required is to ground the input to the feedback Pin 9.

By grounding Pin 9, we have disconnected the feedback loop and the conduction angle is controlled solely by RP1. Further, since the feedback is disconnected, R9 and RP2 are no longer necessary. The Soft-Start feature can still be used to protect the bulb from an inrush of current. This setup can be used in any application that requires manual control of the power delivered to the load (see Figure 15).



R_P=100kΩ C_8=0.22uF

R_7=470kΩ/0.5W C_{13}=4.7uF

R_S=10kΩ/2W R_{10}=200 kΩ

R_6=470kΩ/0.5W C_4=44nF

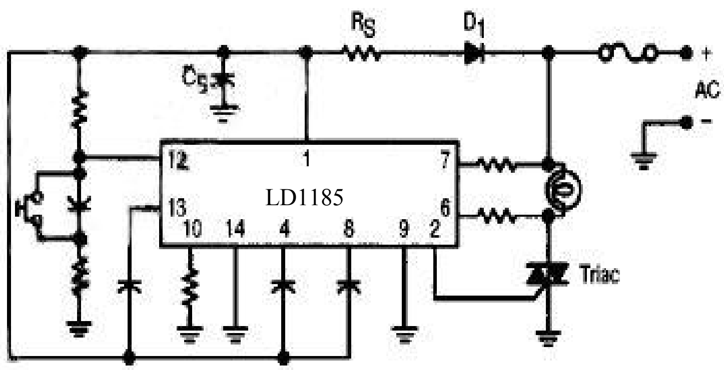
C_S=100uF/16V

Figure 15. Light Dimmer Circuit

Soft Shut-Off

Once again with little modification, the LD1185 can be used to turnoff the load slowly. An example of this is in automatic garage lighting. Typically, lights that are on a timer go off without a warning, usually in the most inopportune time (like when you're about to step over the dog). With a soft shut-off, the light dims out slowly, alerting you that it is about to go off. As in the previous case, the feedback is disconnected and RP1 is replaced with capacitor C12 and a switch (see Figure 16). The turn-off time can be calculated by the following equation: $\Delta t \approx R_{12} \times C_{12}$

(Rl2 is the sum of the two resistors on both sides of C12)



R_S=10kΩ/2W C_4=44nF

R_{10}=200 kΩ R_6=470kΩ/0.5W

C_S=100uF

R_7=470kΩ/0.5W C_{13}=0.47uF

R_{12}=Designer's Choice

C_{12}=Designer's Choice

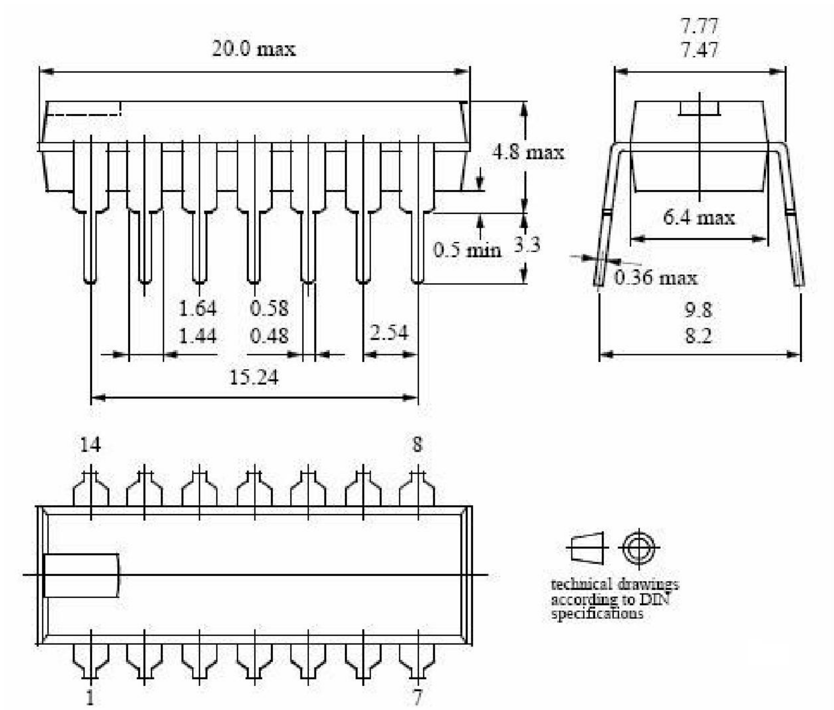
Turn-off Time=R_{12}×C_{12}

Figure 16. Soft Shut-off Circuit

Package Information

DIP14

Dimensions in mm



SOP14

Dimensions in mm