

# MC33363

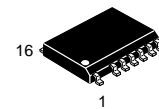
## High Voltage Switching Regulator

The MC33363 is a monolithic high voltage switching regulator that is specifically designed to operate from a rectified 240 Vac line source. This integrated circuit features an on-chip 700 V/1.0 A SenseFET power switch, 450 V active off-line startup FET, duty cycle controlled oscillator, current limiting comparator with a programmable threshold and leading edge blanking, latching pulse width modulator for double pulse suppression, high gain error amplifier, and a trimmed internal bandgap reference. Protective features include cycle-by-cycle current limiting, input undervoltage lockout with hysteresis, output overvoltage protection, and thermal shutdown. This device is available in a 16-lead dual-in-line and wide body surface mount packages.

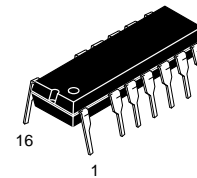
- On-Chip 700 V, 1.0 A SenseFET Power Switch
- Rectified 240 Vac Line Source Operation
- On-Chip 450 V Active Off-Line Startup FET
- Latching PWM for Double Pulse Suppression
- Cycle-By-Cycle Current Limiting
- Input Undervoltage Lockout with Hysteresis
- Output Overvoltage Protection Comparator
- Trimmed Internal Bandgap Reference
- Internal Thermal Shutdown

### HIGH VOLTAGE OFF-LINE SWITCHING REGULATOR

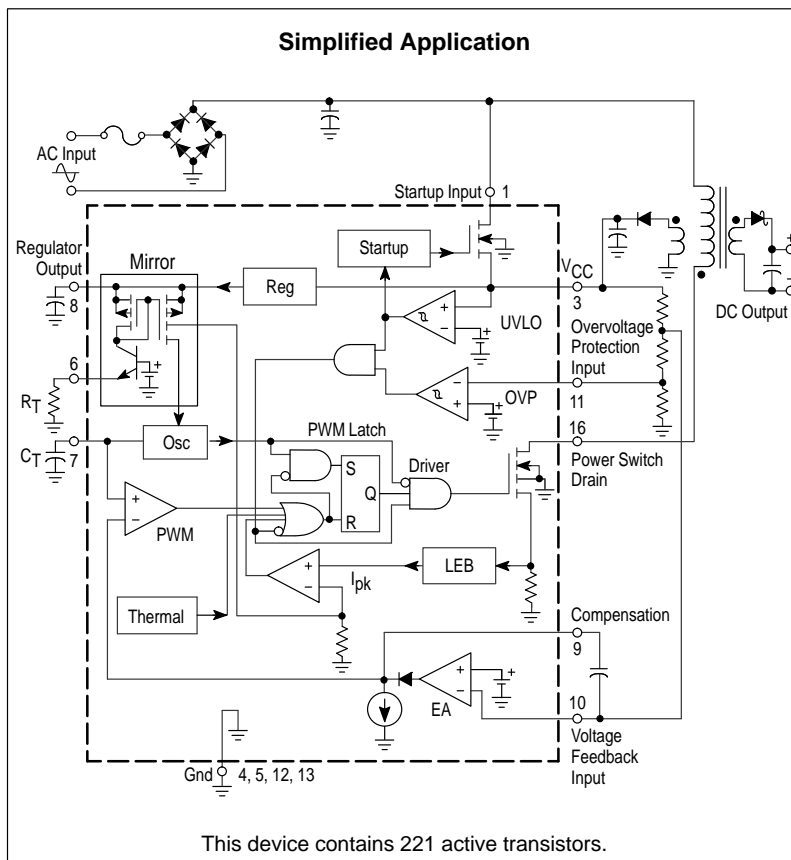
#### SEMICONDUCTOR TECHNICAL DATA



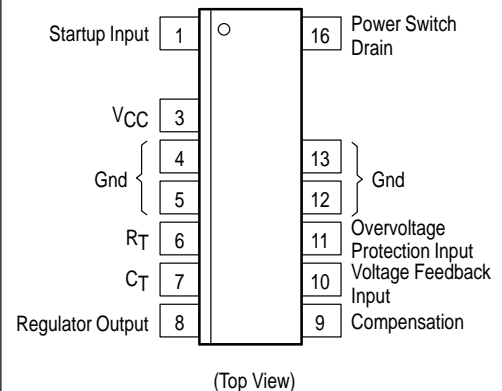
**DW SUFFIX**  
PLASTIC PACKAGE  
CASE 751N  
(SOP-16L)



**P SUFFIX**  
PLASTIC PACKAGE  
CASE 648E  
(DIP-16)



#### PIN CONNECTIONS



#### ORDERING INFORMATION

Device	Operating Temperature Range	Package
MC33363DW	$T_J = -25^\circ \text{ to } +125^\circ \text{C}$	SOP-16L
MC33363P		DIP-16

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## MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Power Switch (Pin 16) Drain Voltage Drain Current	$V_{DS}$ $I_{DS}$	700 1.0	V A
Startup Input Voltage (Pin 1, Note 1) Pin 3 = Gnd Pin 3 $\leq$ 1000 $\mu$ F to ground	$V_{in}$	400 500	V
Power Supply Voltage (Pin 3)	$V_{CC}$	40	V
Input Voltage Range Voltage Feedback Input (Pin 10) Compensation (Pin 9) Overvoltage Protection Input (Pin 11) $R_T$ (Pin 6) $C_T$ (Pin 7)	$V_{IR}$	-1.0 to $V_{reg}$	V
Thermal Characteristics P Suffix, Dual-In-Line Case 648E Thermal Resistance, Junction-to-Air Thermal Resistance, Junction-to-Case (Pins 4, 5, 12, 13) DW Suffix, Surface Mount Case 751N Thermal Resistance, Junction-to-Air Thermal Resistance, Junction-to-Case (Pins 4, 5, 12, 13) Refer to Figures 15 and NO TAG for additional thermal information.	$R_{\theta JA}$ $R_{\theta JC}$  $R_{\theta JA}$ $R_{\theta JC}$	80 15  95 15	$^{\circ}$ C/W
Operating Junction Temperature	$T_J$	- 25 to +150	$^{\circ}$ C
Storage Temperature	$T_{stg}$	- 55 to +150	$^{\circ}$ C

**NOTE:** ESD data available upon request.

**ELECTRICAL CHARACTERISTICS** ( $V_{CC} = 20$  V,  $R_T = 10$  k,  $C_T = 390$  pF,  $C_{pin 8} = 1.0$   $\mu$ F, for typical values  $T_J = 25^{\circ}$ C, for min/max values  $T_J$  is the operating junction temperature range that applies (Note 2), unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit
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### REGULATOR (Pin 8)

Output Voltage ( $I_O = 0$ mA, $T_J = 25^{\circ}$ C)	$V_{reg}$	5.5	6.5	7.5	V
Line Regulation ( $V_{CC} = 20$ V to 40 V)	Reg <sub>line</sub>	-	30	500	mV
Load Regulation ( $I_O = 0$ mA to 10 mA)	Reg <sub>load</sub>	-	44	200	mV
Total Output Variation over Line, Load, and Temperature	$V_{reg}$	5.3	-	8.0	V

### OSCILLATOR (Pin 7)

Frequency $C_T = 390$ pF $T_J = 25^{\circ}$ C ( $V_{CC} = 20$ V) $T_J = T_{low}$ to $T_{high}$ ( $V_{CC} = 20$ V to 40 V) $C_T = 2.0$ nF $T_J = 25^{\circ}$ C ( $V_{CC} = 20$ V) $T_J = T_{low}$ to $T_{high}$ ( $V_{CC} = 20$ V to 40 V)	$f_{OSC}$	260 255	285 -	310 315	kHz
Frequency Change with Voltage ( $V_{CC} = 20$ V to 40 V)	$\Delta f_{OSC}/\Delta V$	-	0.1	2.0	kHz

### ERROR AMPLIFIER (Pins 9, 10)

Voltage Feedback Input Threshold	$V_{FB}$	2.52	2.6	2.68	V
Line Regulation ( $V_{CC} = 20$ V to 40 V, $T_J = 25^{\circ}$ C)	Reg <sub>line</sub>	-	0.6	5.0	mV
Input Bias Current ( $V_{FB} = 2.6$ V)	$I_{IB}$	-	20	500	nA
Open Loop Voltage Gain ( $T_J = 25^{\circ}$ C)	$A_{VOL}$	-	82	-	dB
Gain Bandwidth Product ( $f = 100$ kHz, $T_J = 25^{\circ}$ C)	GBW	-	1.0	-	MHz

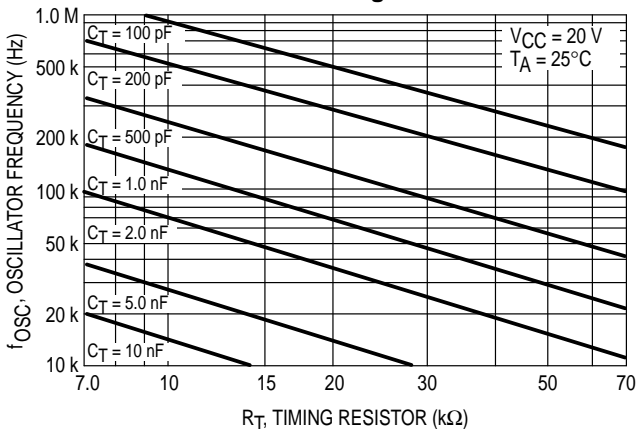
**NOTES:** 1. Maximum power dissipation limits must be observed.  
2. Tested junction temperature range for the MC33363:  
 $T_{low} = -25^{\circ}$ C  $T_{high} = +125^{\circ}$ C

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**ELECTRICAL CHARACTERISTICS (continued)** ( $V_{CC} = 20\text{ V}$ ,  $R_T = 10\text{ k}$ ,  $C_T = 390\text{ pF}$ ,  $C_{Pin\ 8} = 1.0\text{ }\mu\text{F}$ , for typical values  $T_J = 25^\circ\text{C}$ , for min/max values  $T_J$  is the operating junction temperature range that applies (Note 2), unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit
<b>ERROR AMPLIFIER</b> (Pins 9, 10)					
Output Voltage Swing High State ( $I_{Source} = 100\text{ }\mu\text{A}$ , $V_{FB} < 2.0\text{ V}$ ) Low State ( $I_{Sink} = 100\text{ }\mu\text{A}$ , $V_{FB} > 3.0\text{ V}$ )	$V_{OH}$ $V_{OL}$	4.0 –	5.3 0.2	– 0.35	V
<b>OVERVOLTAGE DETECTION</b> (Pin 11)					
Input Threshold Voltage	$V_{th}$	2.47	2.6	2.73	V
Input Bias Current ( $V_{in} = 2.6\text{ V}$ )	$I_{IB}$	–	100	500	nA
<b>PWM COMPARATOR</b> (Pins 7, 9)					
Duty Cycle Maximum ( $V_{FB} = 0\text{ V}$ ) Minimum ( $V_{FB} = 2.7\text{ V}$ )	$DC_{(max)}$ $DC_{(min)}$	48 –	50 0	52 0	%
<b>POWER SWITCH</b> (Pin 16)					
Drain–Source On–State Resistance ( $I_D = 200\text{ mA}$ ) $T_J = 25^\circ\text{C}$ $T_J = T_{low}$ to $T_{high}$	$R_{DS(on)}$	– –	14 –	17 32	$\Omega$
Drain–Source Off–State Leakage Current ( $V_{DS} = 700\text{ V}$ )	$I_{D(off)}$	–	0.2	50	$\mu\text{A}$
Rise Time	$t_r$	–	50	–	ns
Fall Time	$t_f$	–	50	–	ns
<b>OVERCURRENT COMPARATOR</b> (Pin 16)					
Current Limit Threshold ( $R_T = 10\text{ k}$ )	$I_{lim}$	0.5	0.72	0.9	A
<b>STARTUP CONTROL</b> (Pin 1)					
Peak Startup Current ( $V_{in} = 400\text{ V}$ ) $V_{CC} = 0\text{ V}$ $V_{CC} = (V_{th(on)} - 0.2\text{ V})$	$I_{start}$	– –	20 6.0	– –	mA
Off–State Leakage Current ( $V_{in} = 50\text{ V}$ , $V_{CC} = 20\text{ V}$ )	$I_{D(off)}$	–	40	200	$\mu\text{A}$
<b>UNDERVOLTAGE LOCKOUT</b> (Pin 3)					
Startup Threshold ( $V_{CC}$ Increasing)	$V_{th(on)}$	11	15.2	18	V
Minimum Operating Voltage After Turn–On	$V_{CC(min)}$	7.5	9.5	11.5	V
<b>TOTAL DEVICE</b> (Pin 3)					
Power Supply Current Startup ( $V_{CC} = 10\text{ V}$ , Pin 1 Open) Operating	$I_{CC}$	– –	0.25 3.2	0.5 5.0	mA

**Figure 1. Oscillator Frequency versus Timing Resistor**



**Figure 2. Power Switch Peak Drain Current versus Timing Resistor**

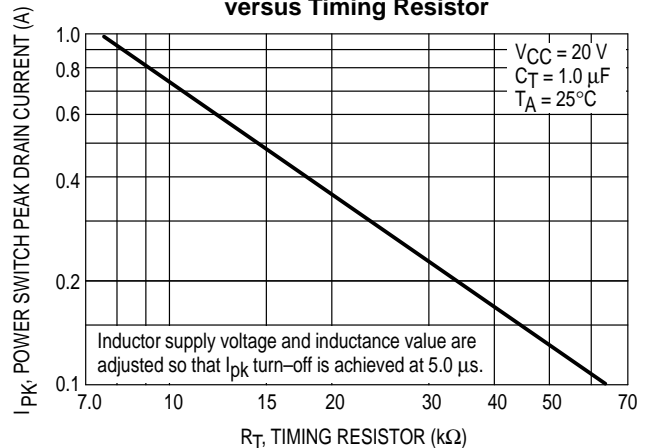


Figure 3. Oscillator Charge/Discharge Current versus Timing Resistor

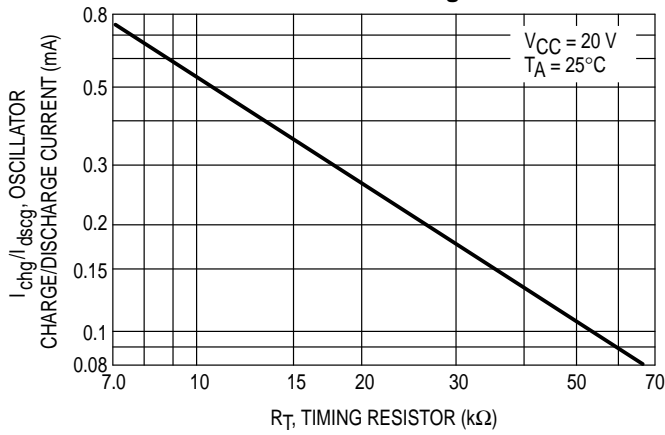


Figure 4. Maximum Output Duty Cycle versus Timing Resistor Ratio

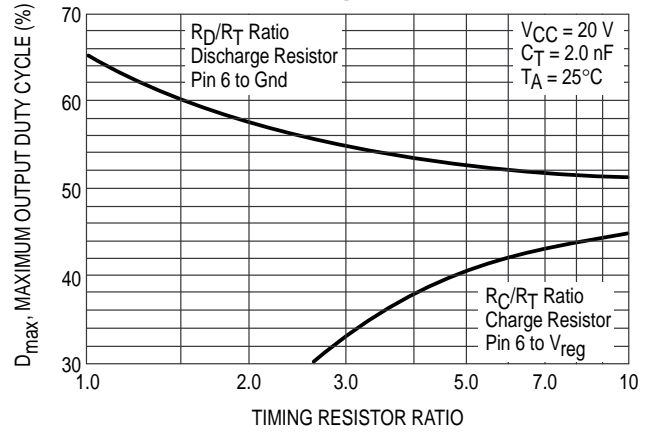


Figure 5. Error Amp Open Loop Gain and Phase versus Frequency

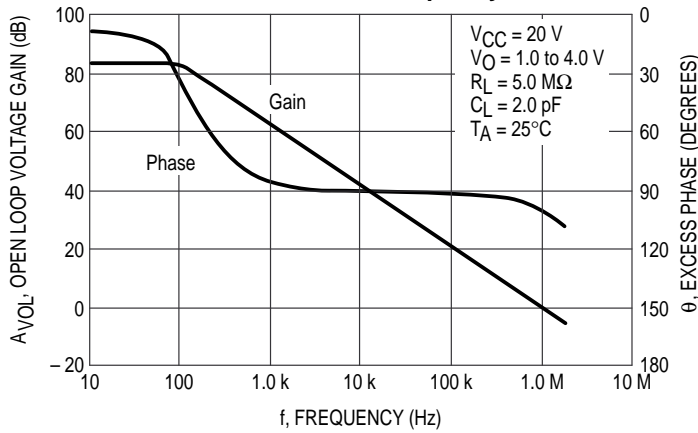


Figure 6. Error Amp Output Saturation Voltage versus Load Current

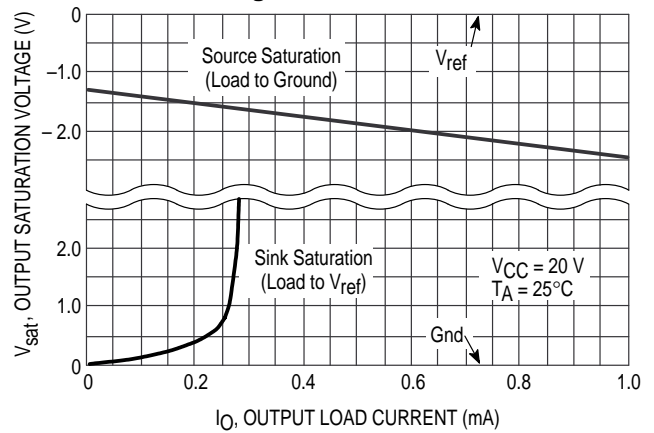


Figure 7. Error Amplifier Small Signal Transient Response

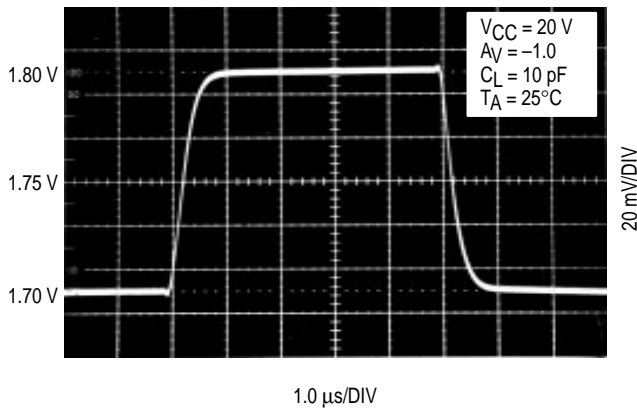
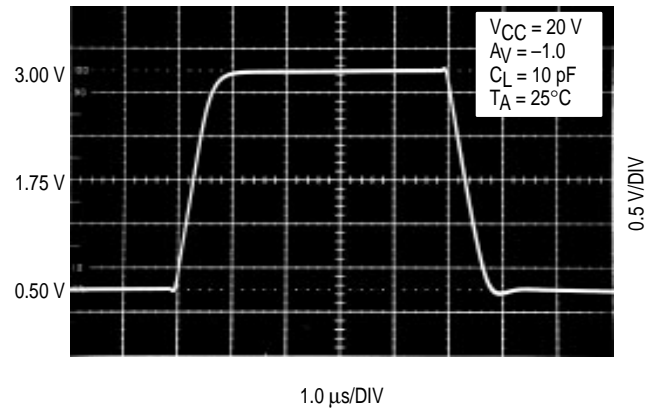
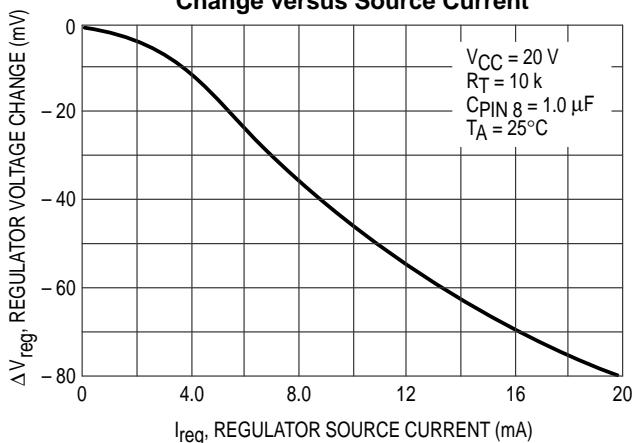


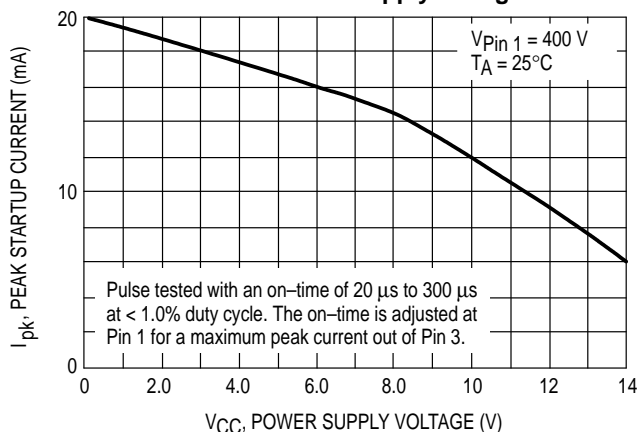
Figure 8. Error Amplifier Large Signal Transient Response



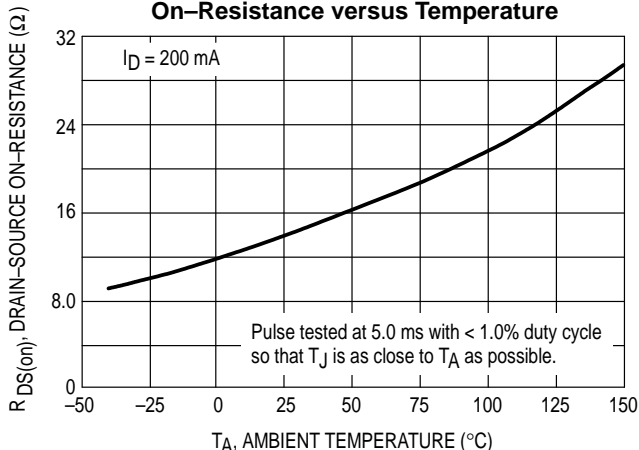
**Figure 9. Regulator Output Voltage Change versus Source Current**



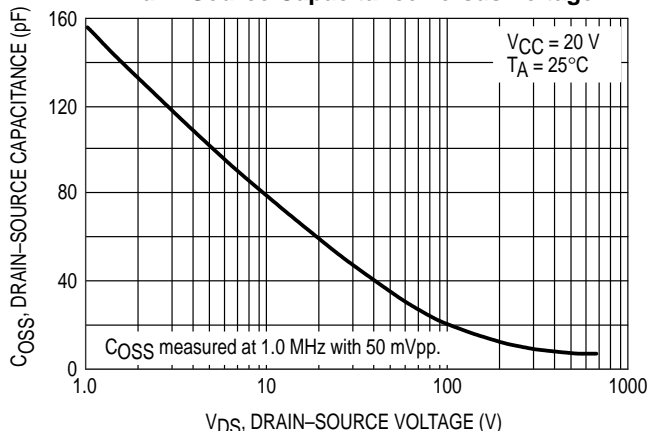
**Figure 10. Peak Startup Current versus Power Supply Voltage**



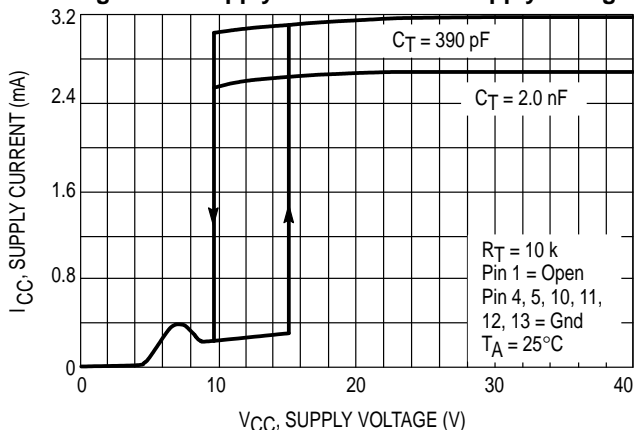
**Figure 11. Power Switch Drain-Source On-Resistance versus Temperature**



**Figure 12. Power Switch Drain-Source Capacitance versus Voltage**



**Figure 13. Supply Current versus Supply Voltage**



**Figure 14. DW and P Suffix Transient Thermal Resistance**

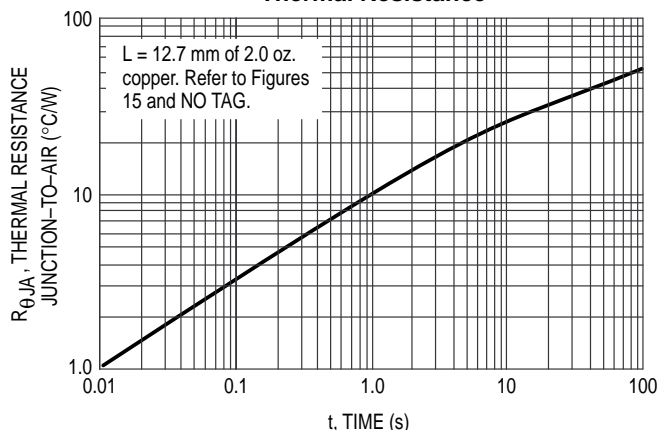


Figure 15. DW Suffix (SOP-16L) Thermal Resistance and Maximum Power Dissipation versus P.C.B. Copper Length

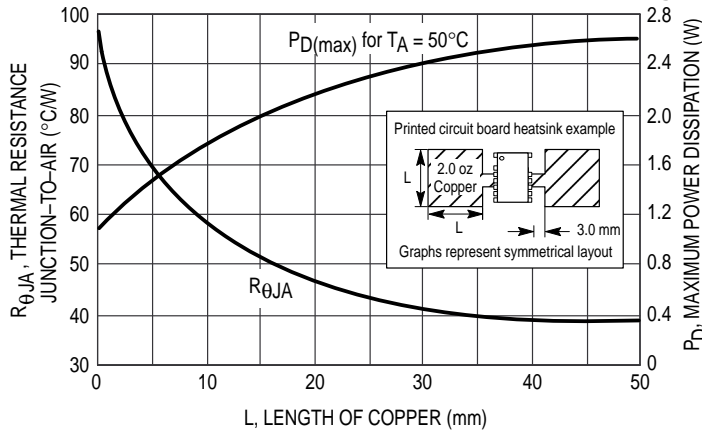
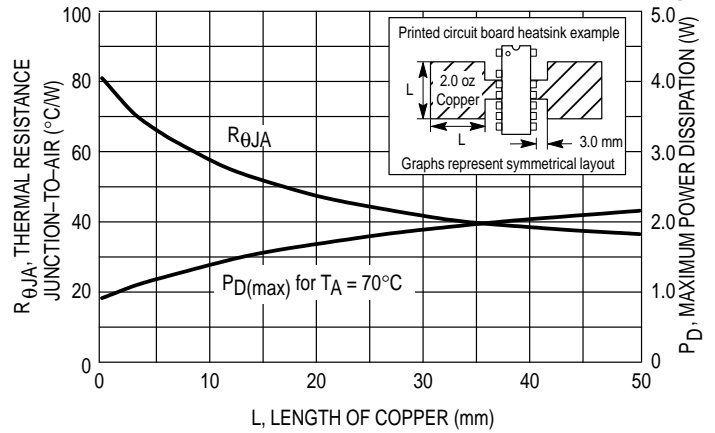


Figure 16. P Suffix (DIP-16) Thermal Resistance and Maximum Power Dissipation versus P.C.B. Copper Length



PIN FUNCTION DESCRIPTION

Pin	Function	Description
1	Startup Input	This pin connects directly to the rectified ac line voltage source. Internally Pin 1 is tied to the drain of a high voltage startup MOSFET. During startup, the MOSFET supplies internal bias, and charges an external capacitor that connects from the V <sub>CC</sub> pin to ground.
2	–	This pin has been omitted for increased spacing between the rectified ac line voltage on Pin 1 and the V <sub>CC</sub> potential on Pin 3.
3	V <sub>CC</sub>	This is the positive supply voltage input. During startup, power is supplied to this input from Pin 1. When V <sub>CC</sub> reaches the UVLO upper threshold, the startup MOSFET turns off and power is supplied from an auxiliary transformer winding.
4, 5, 12, 13	Ground	These pins are the control circuit grounds. They are part of the IC lead frame and provide a thermal path from the die to the printed circuit board.
6	R <sub>T</sub>	Resistor R <sub>T</sub> connects from this pin to ground. The value selected will program the Current Limit Comparator threshold and affect the Oscillator frequency.
7	C <sub>T</sub>	Capacitor C <sub>T</sub> connects from this pin to ground. The value selected, in conjunction with resistor R <sub>T</sub> , programs the Oscillator frequency.
8	Regulator Output	This 6.5 V output is available for biasing external circuitry. It requires an external bypass capacitor of at least 1.0 μF for stability.
9	Compensation	This pin is the Error Amplifier output and is made available for loop compensation. It can be used as an input to directly control the PWM Comparator.
10	Voltage Feedback Input	This is the inverting input of the Error Amplifier. It has a 2.6 V threshold and normally connects through a resistor divider to the converter output, or to a voltage that represents the converter output.
11	Overshoot Protection Input	This input provides runaway output voltage protection due to an external component or connection failure in the control loop feedback signal path. It has a 2.6 V threshold and normally connects through a resistor divider to the converter output, or to a voltage that represents the converter output.
14, 15	–	These pins have been omitted for increased spacing between the high voltages present on the Power Switch Drain, and the ground potential on Pins 12 and 13.
16	Power Switch Drain	This pin is designed to directly drive the converter transformer and is capable of switching a maximum of 700 V and 1.0 A.

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Figure 17. Representative Block Diagram

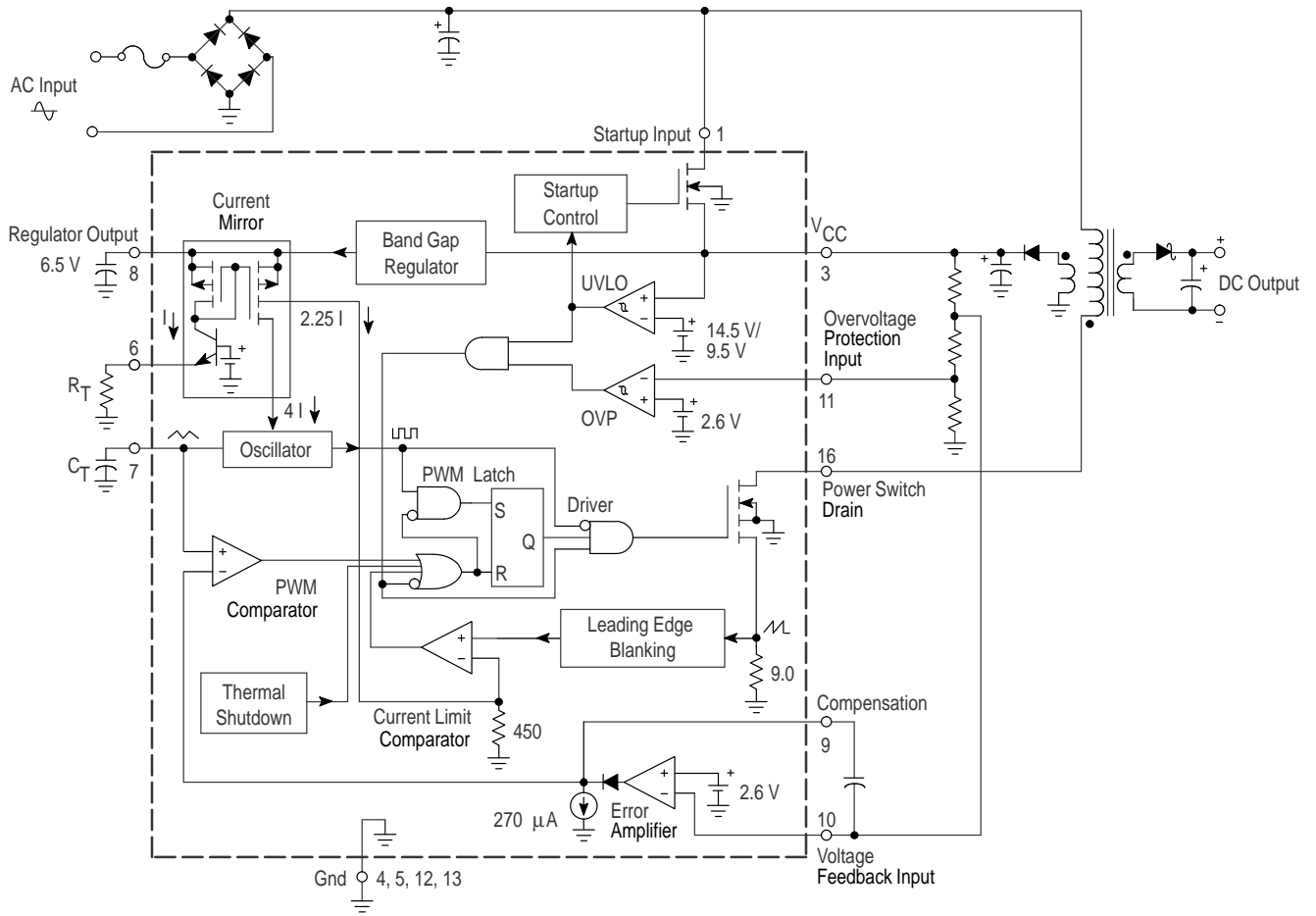
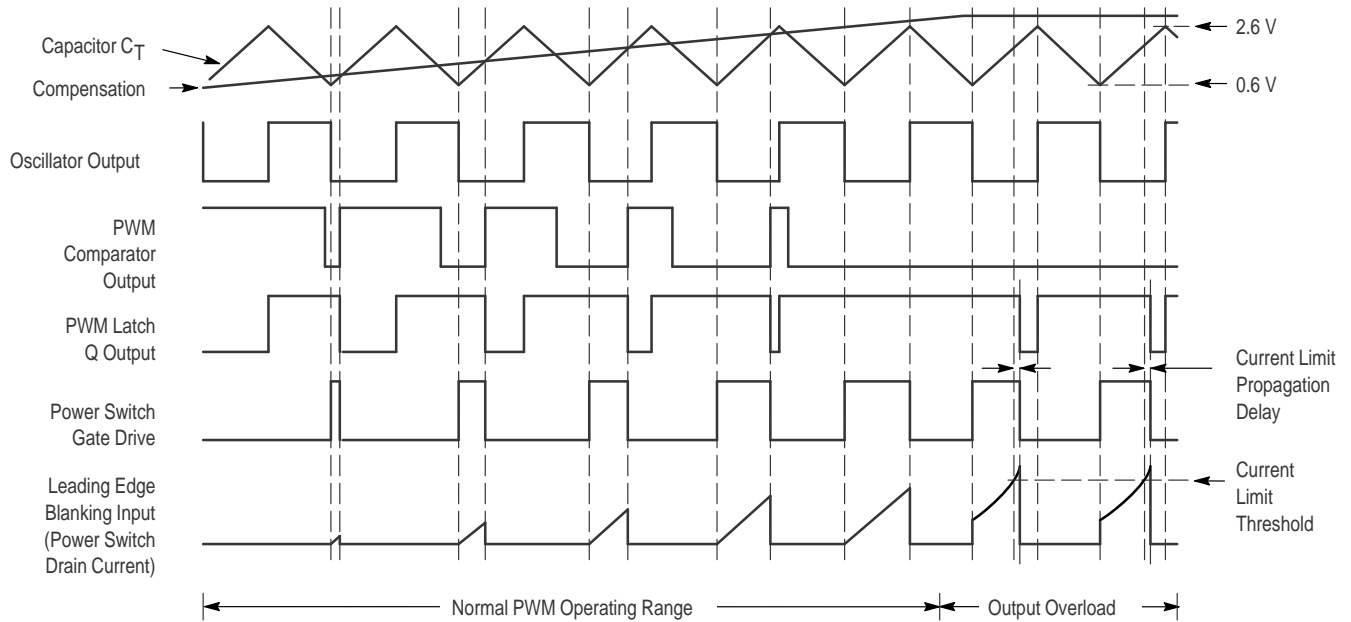


Figure 18. Timing Diagram







The Power Switch is designed to directly drive the converter transformer and is capable of switching a maximum of 700 V and 1.0 A. Proper device voltage snubbing and heatsinking are required for reliable operation.

A Leading Edge Blanking circuit was placed in the current sensing signal path. This circuit prevents a premature reset of the PWM Latch. The premature reset is generated each time the Power Switch is driven into conduction. It appears as a narrow voltage spike across the current sense resistor, and is due to the MOSFET gate to source capacitance, transformer interwinding capacitance, and output rectifier recovery time. The Leading Edge Blanking circuit has a dynamic behavior in that it masks the current signal until the Power Switch turn-on transition is completed. The current limit propagation delay time is typically 233 ns. This time is measured from when an overcurrent appears at the Power Switch drain, to the beginning of turn-off.

### Error Amplifier

An fully compensated Error Amplifier with access to the inverting input and output is provided for primary side voltage sensing, Figure 17. It features a typical dc voltage gain of 82 dB, and a unity gain bandwidth of 1.0 MHz with 78 degrees of phase margin, Figure 5. The noninverting input is internally biased at  $2.6\text{ V} \pm 3.1\%$  and is not pinned out. The Error Amplifier output is pinned out for external loop compensation and as a means for directly driving the PWM Comparator. The output was designed with a limited sink current capability of  $270\text{ }\mu\text{A}$ , allowing it to be easily overridden with a pull-up resistor. This is desirable in applications that require secondary side voltage sensing, Figure 20. In this application, the Voltage Feedback Input is connected to the Regulator Output. This disables the Error Amplifier by placing its output into the sink state, allowing the optocoupler transistor to directly control the PWM Comparator.

### Overvoltage Protection

An Overvoltage Protection Comparator is included to eliminate the possibility of runaway output voltage. This condition can occur if the control loop feedback signal path is broken due to an external component or connection failure. The comparator is normally used to monitor the primary side  $V_{CC}$  voltage. When the 2.6 V threshold is exceeded, it will immediately turn off the Power Switch, and protect the load from a severe overvoltage condition. This input can also be driven from external circuitry to inhibit converter operation.

### Undervoltage Lockout

An Undervoltage Lockout comparator has been incorporated to guarantee that the integrated circuit has sufficient voltage to be fully functional before the output stage is enabled. The UVLO comparator monitors the  $V_{CC}$  voltage at Pin 3 and when it exceeds 14.5 V, the reset signal is removed from the PWM Latch allowing operation of the Power Switch. To prevent erratic switching as the threshold is crossed, 5.0 V of hysteresis is provided.

### Startup Control

An internal Startup Control circuit with a high voltage enhancement mode MOSFET is included within the MC33363. This circuitry allows for increased converter efficiency by eliminating the external startup resistor, and its associated power dissipation, commonly used in most off-line converters that utilize a UC3842 type of controller. Rectified ac line voltage is applied to the Startup Input, Pin 1. This causes the MOSFET to enhance and supply internal bias as well as charge current to the  $V_{CC}$  bypass capacitor that connects from Pin 3 to ground. When  $V_{CC}$  reaches the UVLO upper threshold of 15.2 V, the IC commences operation and the startup MOSFET is turned off. Operating bias is now derived from the auxiliary transformer winding, and all of the device power is efficiently converted down from the rectified ac line.

The startup MOSFET will provide an initial peak current of 20 mA, Figure 10, which decreases rapidly as  $V_{CC}$  and the die temperature rise. The steady state current will self limit in the range of 8.0 mA with  $V_{CC}$  shorted to ground. The startup MOSFET is rated at a maximum of 400 V with  $V_{CC}$  shorted to ground, and 500 V when charging a  $V_{CC}$  capacitor of 1000  $\mu\text{F}$  or less.

### Regulator

A low current 6.5 V regulated output is available for biasing the Error Amplifier and any additional control system circuitry. It is capable of up to 10 mA and has short-circuit protection. This output requires an external bypass capacitor of at least 1.0  $\mu\text{F}$  for stability.

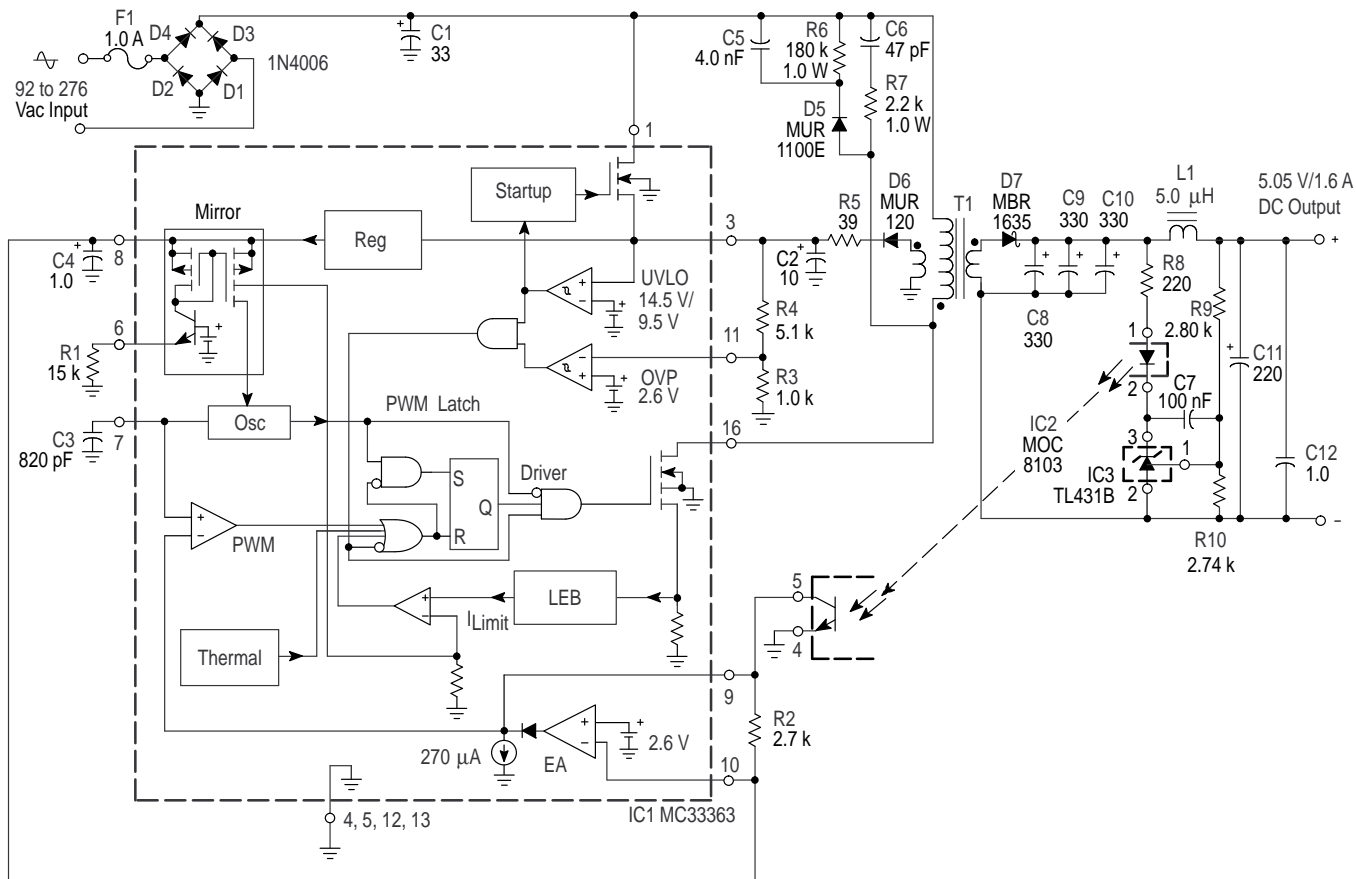
### Thermal Shutdown and Package

Internal thermal circuitry is provided to protect the Power Switch in the event that the maximum junction temperature is exceeded. When activated, typically at  $155^{\circ}\text{C}$ , the Latch is forced into a 'reset' state, disabling the Power Switch. The Latch is allowed to 'set' when the Power Switch temperature falls below  $145^{\circ}\text{C}$ . This feature is provided to prevent catastrophic failures from accidental device overheating. It is not intended to be used as a substitute for proper heatsinking.

The MC33363 is contained in a heatsinkable plastic dual-in-line package in which the die is mounted on a special heat tab copper alloy lead frame. This tab consists of the four center ground pins that are specifically designed to improve thermal conduction from the die to the circuit board. Figures 15 and NO TAG show a simple and effective method of utilizing the printed circuit board medium as a heat dissipater by soldering these pins to an adequate area of copper foil. This permits the use of standard layout and mounting practices while having the ability to halve the junction to air thermal resistance. The examples are for a symmetrical layout on a single-sided board with two ounce per square foot of copper. Figure 22 shows a practical example of a printed circuit board layout that utilizes the copper foil as a heat dissipater. Note that a jumper was added to the layout from Pins 8 to 10 in order to enhance the copper area near the device for improved thermal conductivity. The application circuit requires two ounce copper foil in order to obtain 8.0 watts of continuous output power at room temperature.

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## Figure 20. 8.0 W Off-Line Converter



## Figure 21. Converter Test Data

Test	Conditions	Results
Line Regulation	$V_{in} = 92 \text{ Vac to } 276 \text{ Vac}, I_O = 1.6 \text{ A}$	$\Delta = 1.0 \text{ mV}$
Load Regulation	$V_{in} = 115 \text{ Vac}, I_O = 0.4 \text{ A to } 1.6 \text{ A}$	$\Delta = 4.0 \text{ mV}$
	$V_{in} = 230 \text{ Vac}, I_O = 0.4 \text{ A to } 1.6 \text{ A}$	$\Delta = 4.0 \text{ mV}$
Output Ripple	$V_{in} = 115 \text{ Vac}, I_O = 1.6 \text{ A}$	Triangular = 2.0 mVpp, Spike = 12 mVpp
	$V_{in} = 230 \text{ Vac}, I_O = 1.6 \text{ A}$	Triangular = 2.0 mVpp, Spike = 12 mVpp
Efficiency	$V_{in} = 115 \text{ Vac}, I_O = 1.6 \text{ A}$	78.6%*
	$V_{in} = 230 \text{ Vac}, I_O = 1.6 \text{ A}$	75.6%

This data was taken with the components listed below mounted on the printed circuit board shown in Figure 22.

\* With MBR2535CTL, 79.8% efficiency. PCB layout modification is required to use this rectifier.

For high efficiency and small circuit board size, the Sanyo Os-Con capacitors are recommended for C8, C9, C10 and C11.

C8, C9, C10 = Sanyo Os-Con #6SA330M, 330  $\mu\text{F}$  6.3 V.

C11 = Sanyo Os-Con #10SA220M, 220  $\mu\text{F}$  10 V.

L1 = Coilcraft S5088-A, 5.0  $\mu\text{H}$ , 0.11  $\Omega$ .

T1 = Coilcraft S5502-A

Primary: 77 turns of # 28 AWG, Pin 1 = start, Pin 8 = finish.

Two layers 0.002" Mylar tape.

Secondary: 5 turns of # 22 AWG, 2 strands bifilar wound, Pin 5 = start, Pin 4 = finish.

Two layers 0.002" Mylar tape.

Auxiliary: 13 turns of # 28 AWG wound in center of bobbin, Pin 2 = start, Pin 7 = finish.

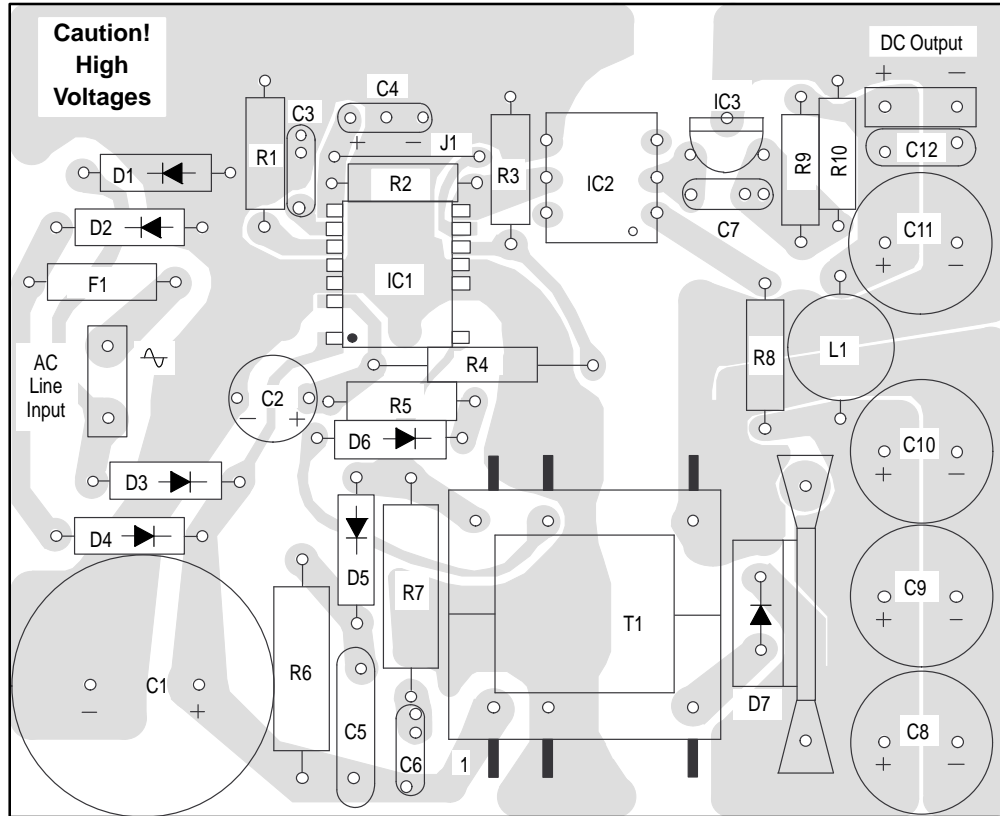
Two layers 0.002" Mylar tape.

Gap: 0.006" total for a primary inductance ( $L_p$ ) of 1.0 mH.

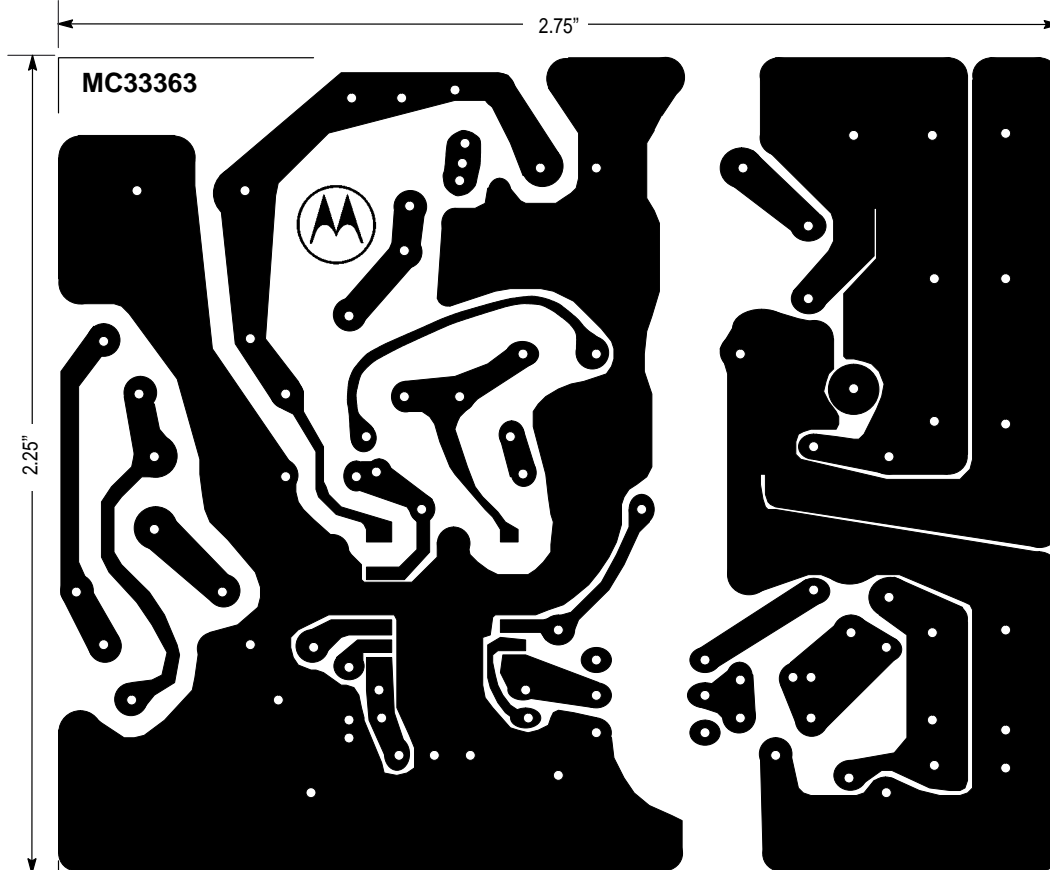
Core and Bobbin: Coilcraft PT1950, E187, 3F3 material.

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Figure 22. Printed Circuit Board and Component Layout  
(Circuit of Figure 20)

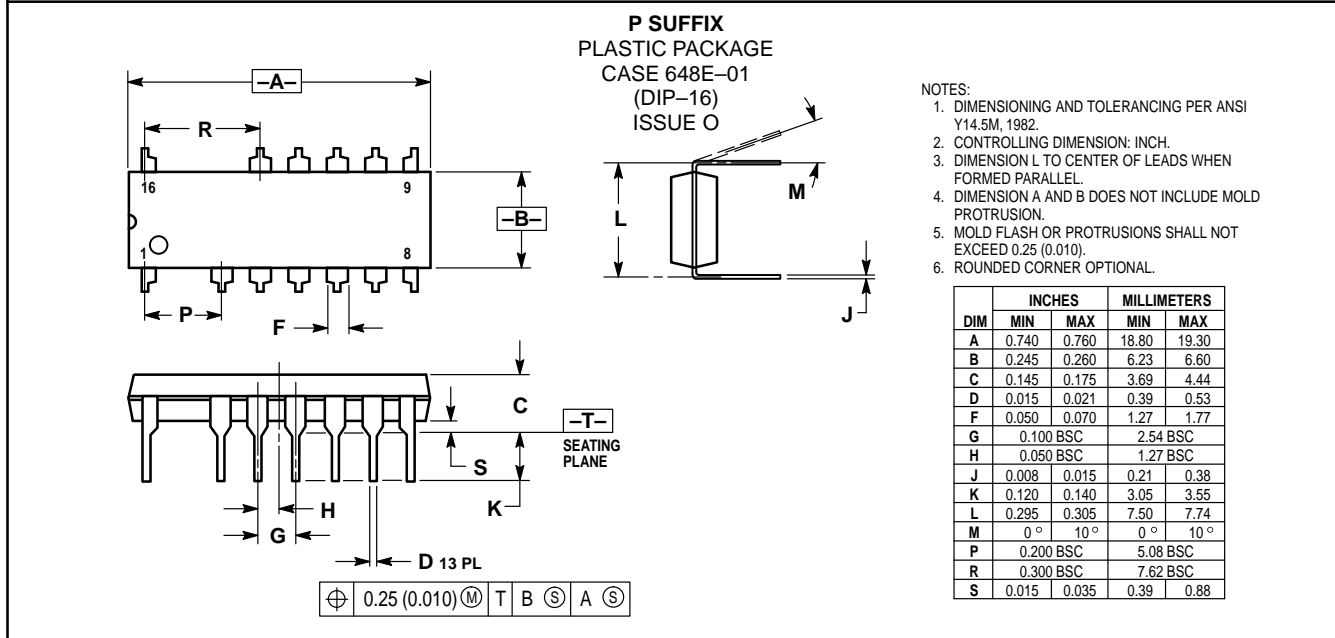
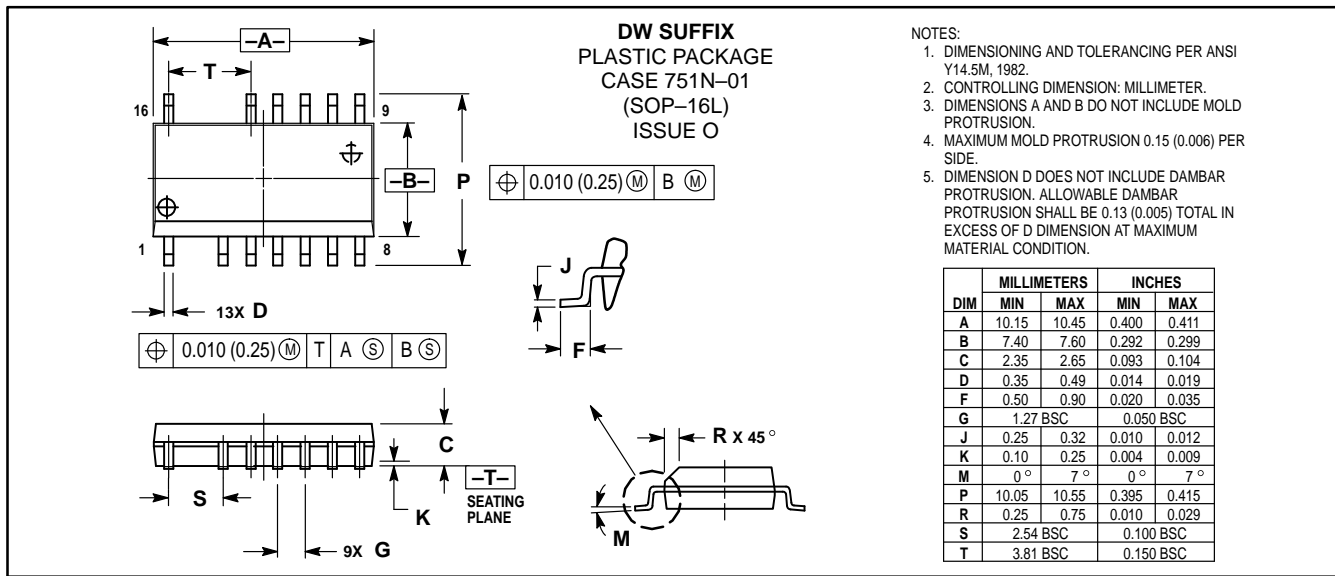


(Top View)



(Bottom View)

OUTLINE DIMENSIONS



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