

# ML4818

## Phase Modulation/Soft Switching Controller

### Features

- Full bridge phase modulation zero voltage switching circuit with programmable ZV transition times
- Constant frequency operation to 500kHz
- Current mode operation
- Cycle-by-cycle current limiting with integrating fault detection and restart delay
- Precision buffered 5V reference (+1%)
- Four 1.5A peak current totem-pole output drivers
- Under-voltage lockout circuit with 6V hysteresis
- Power DIP package

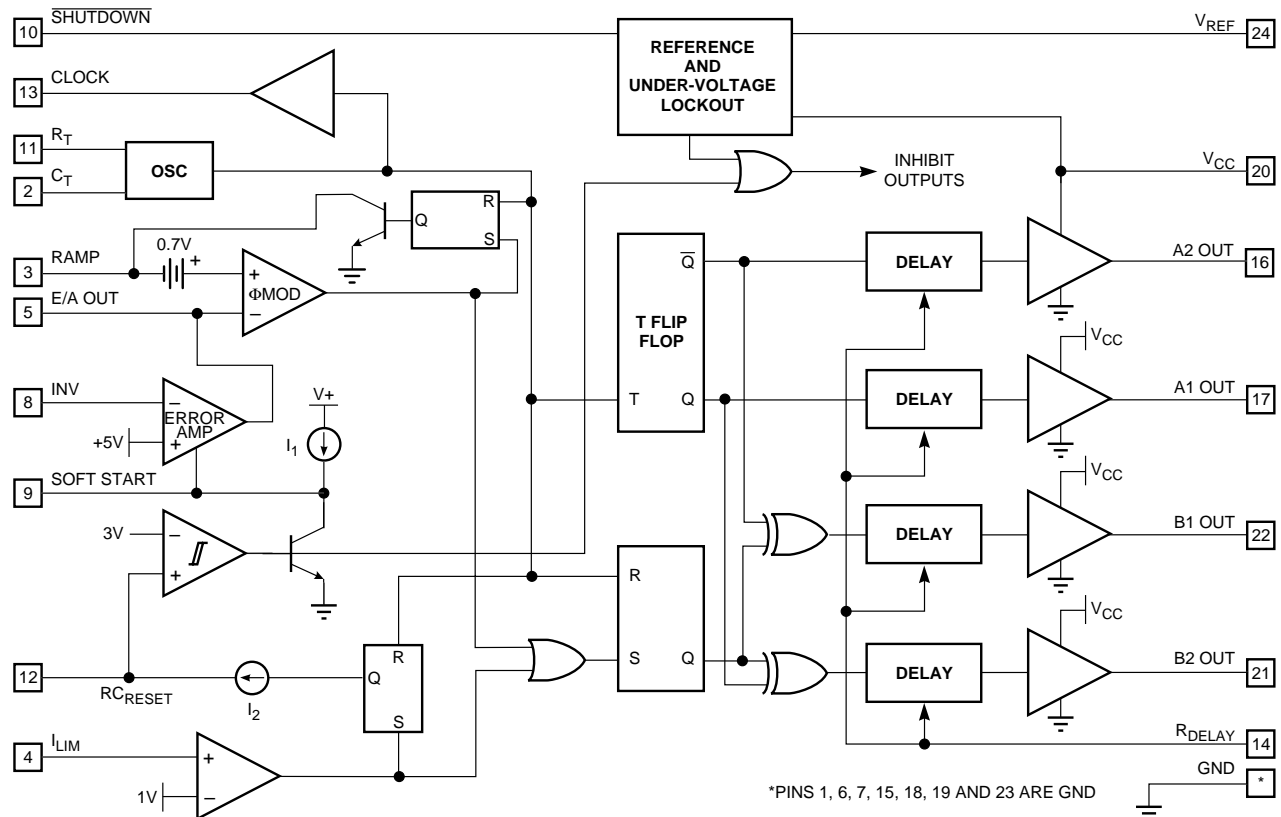
### General Description

The ML4818 is a complete phase modulation control IC suitable for full bridge soft switching converters. Unlike conventional PWM circuits, the phase modulation technique allows for zero-voltage switching transitions and square wave drive across the transformer. The IC modulates the phases of the two sides of the bridge to control output power.

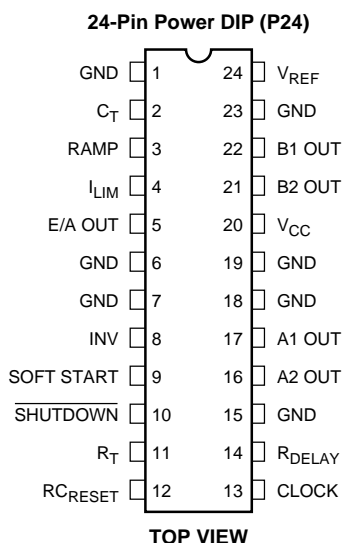
The ML4818 can be operated in current mode. The delay times for the outputs are externally programmable to allow the zero-voltage switching transitions to take place.

Pulse-by-pulse current limit, integrating fault detection, and soft start reset are provided. The under-voltage lockout circuit features a 6V hysteresis with a low starting current to allow off-line start up with a low power bleed resistor. A shutdown function powers down the IC, putting it into a low quiescent state.

### Block Diagram



## Pin Configuration



## Pin Description

Pin	Name	Function
1	GND	Ground
2	$C_T$	Timing capacitor for oscillator
3	RAMP	Non-inverting input to main comparator. Connected to current sense resistor for current mode
4	$I_{LIM}$	Current limit sense pin. Normally connected to current sense resistor
5	E/A OUT	Output of error amplifier and input to PWM comparator
6,7	GND	Ground and substrate
8	INV	Inverting input to error amp
9	SOFT START	Normally connected to soft start capacitor
10	$\overline{SHUTDOWN}$	Pulling this pin low puts the IC into a power down mode and turns off all outputs. This pin is internally pulled up to $V_{REF}$ .
11	$R_T$	Resistor which sets discharge current for oscillator timing capacitor
12	$RC_{RESET}$	Timing elements for Integrating fault detection and reset delay circuits
13	CLOCK	Oscillator output
14	$R_{DELAY}$	Resistor to ground on this pin programs the amount of delay from the time an output turns off until its complementary output turns on
15	GND	Ground
16	A2 OUT	High current totem pole output A1
17	A1 OUT	High current totem pole output A2
18,19	GND	Ground and substrate
20	$V_{CC}$	Positive supply for the IC
21	B2 OUT	High current totem pole output B1
22	B1 OUT	High current totem pole output B2
23	GND	Ground
24	$V_{REF}$	Buffered output for the 5V voltage reference

## Absolute Maximum Ratings

Absolute Maximum Ratings are those values, beyond which the device could be permanently damaged. Absolute maximum ratings are stress ratings only and functional device operation is not implied.

Parameter	Min.	Max.	Units
$V_{CC}$		30	V
Output Driver Current, Source or Sink DC		0.5	A
Pulse (0.5 $\mu$ s)		1.5	A
Analog Inputs ( $C_T$ , RAMP, $I_{LIM}$ , E/A OUT, INV, SOFT START, $R_{C_{RESET}}$ )	-0.3	6	V
CLOCK Output Current ( $R_T$ )		-5	mA
Error Amplifier Output Current (E/A OUT)		5	mA
SOFT START Sink Current		50	mA
Oscillator Charging Current ( $C_T$ )		-5	mA
Junction Temperature		150	$^{\circ}$ C
Storage Temperature Range	-65	150	$^{\circ}$ C
Lead Temperature (Soldering 10 Sec)		260	$^{\circ}$ C
Thermal Resistance ( $\theta_{JA}$ ) Plastic Power DIP		40	$^{\circ}$ C/W

## Operating Conditions

Parameter	Min.	Max.	Units
Operating Temperature Range	0	70	$^{\circ}$ C

## Electrical Characteristics

Unless otherwise specified,  $V_{CC} = 15V$ ,  $R_T = 12.7k\Omega$ ,  $C_T = 250pF$ ,  $R_{CLK} = 3k\Omega$ ,  $R_{DELAY} = 5k\Omega$ ,  $T_A =$  Operating Temperature Range (Note 1).

Parameter	Conditions	Min.	Typ.	Max.	Units
<b>Oscillator</b>					
Initial Accuracy	$T_A=25^{\circ}$ C	410	450	525	kHz
Voltage Stability	$12V < V_{CC} < 25V$		-0.3		%/V
Temperature Stability			0.2		%
Total Variation	line, temp.	375		525	kHz
$C_T$ Discharge Current	$V_{C_T}=2V$	4.7	5.5	6.3	mA
Clock Out High		2.4	3.1	6	V
Clock Out Low			0	0.4	V
Ramp Peak		0	4.1		V
Ramp Valley			1.5	5	V
Ramp Valley to Peak		0	2.6	5	V
<b>Reference</b>					
Output Voltage	$T_A=25^{\circ}$ C, $I_O=1mA$	4.95	5.0	5.05	V
Line Regulation	$12V < V_{CC} < 25V$	-20	2	20	mV
Load Regulation	$1mA < I_O < 10mA$	-20	3	20	mV

**Electrical Characteristics** (continued)

Unless otherwise specified,  $V_{CC} = 15V$ ,  $R_T = 12.7k\Omega$ ,  $C_T = 250pF$ ,  $R_{CLK} = 3k\Omega$ ,  $R_{DELAY} = 5k\Omega$ ,  $T_A =$  Operating Temperature Range (Note 1).

Parameter	Conditions	Min.	Typ.	Max.	Units
Temperature Stability			0.2		mV/°C
Total Variation		4.85		5.15	V
Output Noise Voltage	10Hz to 10kHz		50		mV
Long Term Stability	$T_j = 125^\circ C$ , 1000 hrs		5	25	mV
Short Circuit Current	$V_{REF} = 0V$	-20	-50		mA
<b>Error Amplifier</b>					
Input Offset Voltage		-40		30	mV
Input Bias Current		-3	0.6	3	$\mu A$
Input Offset Current			0.1	1	$\mu A$
Open Loop Gain	$1 < V_O < 4V$	70	75		dB
PSRR	$12 < V_{CC} < 25V$	65	80		dB
Output Sink Current	$V_{EA OUT} = 1V$	1	3.2		mA
Output Source Current	$V_{EA OUT} = 5.1V$	-0.5	-2.2	-20	mA
Output High Voltage	$I_{EA OUT} = -0.5mA$	5.0	5.5	6.0	V
Output Low Voltage	$I_{EA OUT} = 1mA$			0.8	V
Unity Gain Bandwidth		2.0	2.8		MHz
Slew Rate			8.5		V/ $\mu s$
<b>Phase Modulator</b>					
RAMP Bias Current	$V_{RAMP} = 2.5V$		-1	-10	$\mu A$
EA OUT Zero DC Threshold	$V_{RAMP} = 0V$	0.4	0.6	0.9	V
$t_{PD}$ , RAMP to Output			50	80	ns
$t_{DELAY}$	$C_L = 1nF$	99	200	250	ns
$R_{DELAY}$ Voltage		4	4.3	5V	V
<b>Soft Start</b>					
Charge Current	$V_{SOFT START} = 4V$	-15	-25	-30	$\mu A$
Discharge Current	$V_{SOFT START} = 1V$	10	20	30	mA
<b>Current Limit/Shutdown</b>					
$I_{LIM}$ Bias Current	$0V < V_{ILIM} < 4V$	-10	-1	10	$\mu A$
Current Limit Threshold	$V_{SHUTDOWN} = 0V$	0.92	1.02	1.12	V
$t_{PD}$ , $I_{LIM}$			50		ns
$R_{C_{RESET}}$ Shutdown Threshold		3.15	3.4	3.65	V
$R_{C_{RESET}}$ Restart Threshold		1.0	1.3	1.6	V
$R_{C_{RESET}}$ Charging Current	$V_{ILIM} = 2V$ , $V_{RC_{RESET}} = 1.5V$	-400	-523	-1000	$\mu A$
SHUTDOWN Threshold		2.0	2.4	2.8	V
SHUTDOWN Input Bias Current	$V_{SHUTDOWN} = 0$	-100	-25	10	$\mu A$

## Electrical Characteristics (continued)

Unless otherwise specified,  $V_{CC} = 15V$ ,  $R_T = 12.7k\Omega$ ,  $C_T = 250pF$ ,  $R_{CLK} = 3k\Omega$ ,  $R_{DELAY} = 5k\Omega$ ,  $T_A =$  Operating Temperature Range (Note 1).

Parameter	Conditions	Min.	Typ.	Max.	Units
<b>Output</b>					
Output Low Level	$I_{OUT} = 20mA$		0.1	0.4	V
	$I_{OUT} = 200mA$ , $T_A = 25^\circ C$		0.7	2.8	V
Output High Level	$I_{OUT} = -20mA$	12.0	13.5		V
	$I_{OUT} = -200mA$ , $T_A = 25^\circ C$	11.0	13.0		V
Rise/Fall Time	$CL = 1000pF$		50	75	ns
<b>Under-Voltage Lockout</b>					
Start Threshold		15.5	16.5	17.2	V
Stop Threshold		9.25	10.2	10.7	V
<b>Supply</b>					
Start Up Current	$V_{CC} < 15.8V$		3	4	mA
$I_{CC}$	$V_{INV} = 4V$ , $V_{RAMP} = V_{ILIM} = 0V$ , $C_L = 1nF$ , $T_A = 25^\circ C$ (Note 2)		60	70	mA

### Notes

- Limits are guaranteed by 100% testing, sampling, or correlation with worst-case test conditions.
- $V_{CC}$  must be brought above the UVLO start voltage (17.2V) before dropping to  $V_{CC} = 15V$  to ensure start-up.

# Functional Description

## Phase Modulator

Power is controlled by modulating the switching phase on sides A and B of the full H-bridge converter (Figure 1). Power is delivered to the output through the transformer secondary. The power conversion process is described by the following sequence and illustrated by the timing diagram of Figure 2:

1. A2 and B1 are high (Q1 and Q2 are on), beginning the power conversion cycle.
2. After the  $\Phi$  MOD comparator trips, B1 goes low turning off Q2. The parasitic drain-to-source capacitances of Q2 and Q4 charge to +VIN. This forces the drain-to-source voltage across Q3 to 0V.

3. B2 now goes high after  $t_{DELAY}$  (set by  $R_{DELAY}$ ). Since the voltage across Q3 is now 0V, B2 turns Q3 on at zero voltage.
4. The CLOCK now goes high turning A2 off. During this period, Q1 and Q2 and Q4 are off. The transformer leakage current discharges the drain-to-source capacitance on Q4 until there is 0V across it.
5. A1 will remain low for a period defined by  $t_{DELAY}$ , then it goes high. The voltage across Q4 is now 0V as A1 turns it on at zero voltage.
6. The previous sequence is now repeated with the opposite polarity on all outputs (see Figure 2).

The above sequence is then repeated but with the opposite polarity on all outputs.

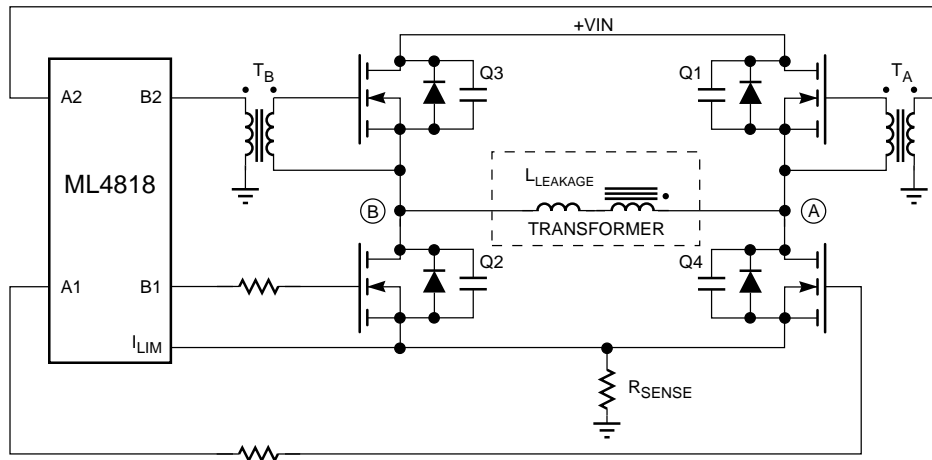


Figure 1. Simplified diagram of Phase Modulated power Outputs

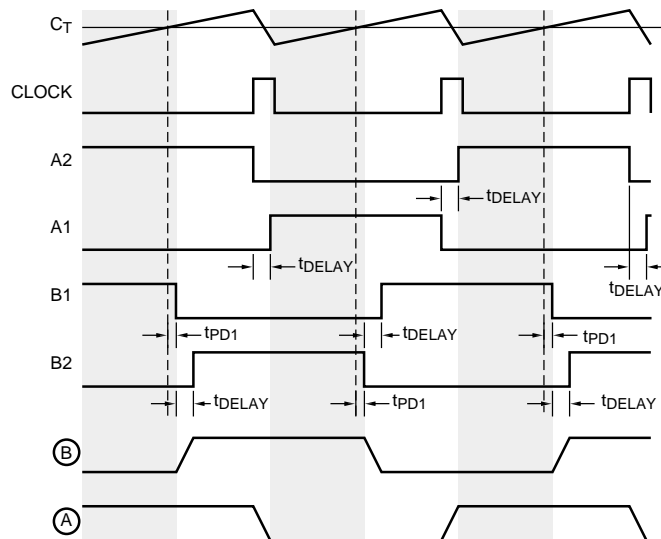


Figure 2. Phase Modulation control waveforms (Shaded areas indicate a power cycle)

The ML4818 can also be used in current mode by sensing load current on the RAMP input (pin 3).

The four output delay timers are programmed via an external  $R_{DELAY}$  resistor as shown below. This resistor value should be no less than  $1k\Omega$ . Expressing  $R_{DELAY}$  in  $k\Omega$  the delay, in ns is:

$$T_{DELAY} = \langle 33 \times R_{DELAY} \rangle + 45 \quad (1)$$

The ML4818 contains special logic circuits to provide for voltage mode feed-forward and lock out long pulses into the internal logic. This prevents instability from occurring when the  $\Phi$  Comparator trips in voltage mode.

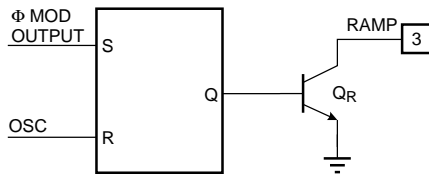


Figure 3. Voltage Feed-Forward Circuit

The collector of  $Q_R$  in figure 3 is high only during a power cycle. When the power cycle terminates, RAMP is pulled low. In voltage mode operation, a capacitor is connected from RAMP to GND with a resistor from RAMP to  $V_{IN}$  to provide input voltage feed forward.

**Oscillator**

The ML4818 oscillator charges the external capacitor,  $C_T$ , with a current ( $I_{SET}$ ) equal to  $5/R_T$ . When the  $C_T$  voltage reaches the upper threshold (Ramp Peak), the comparator changes state, turning on the current sink which discharges  $C_T$  to the lower threshold (Ramp Valley). The  $C_T$  pin is clamped to Ramp Valley by  $Q1$  (Figure 5) to prevent inaccuracy due to undershoot on  $C_T$ .

To use the CLOCK output for driving external synchronization circuitry, a pull-down resistor is required from CLOCK to GND.

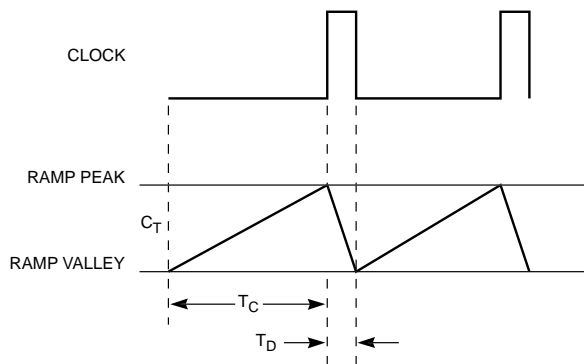


Figure 4. Oscillator Timing Diagram

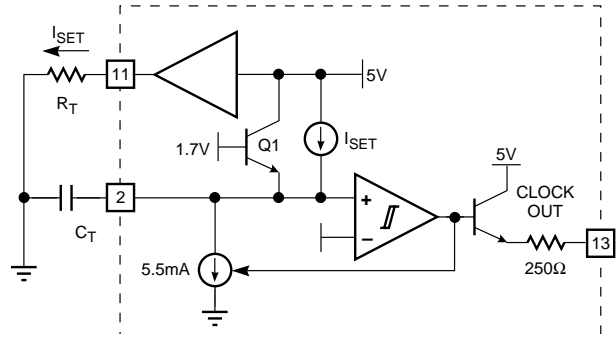


Figure 5. Oscillator Block Diagram

For frequencies of less than 500kHz, oscillator frequency can be set by using the following formulae:

$$f_{osc} = \frac{1}{0.52C_T R_T + 500C_T} \quad (2)$$

**Error Amplifier**

The ML4818 error amplifier is a 2.5MHz bandwidth, 8.5V/ $\mu$ s slew rate op-amp with provision for limiting the positive output voltage swing (output inhibit line) to implement the soft start function. The error amplifier output source current is limited to 4.5mA.

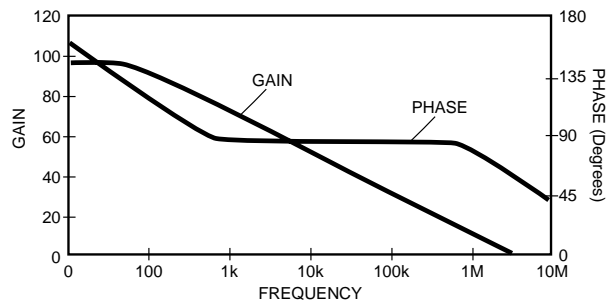


Figure 6. Error Amplifier Open-Loop Gain and Phase vs. Frequency

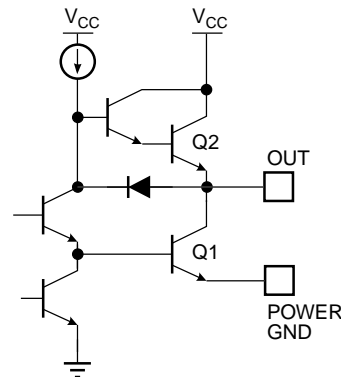


Figure 7. Power Driver Simplified Schematic

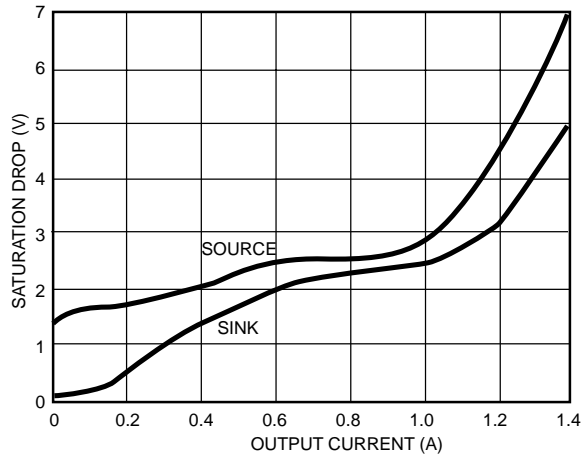


Figure 8. Output Drive Saturation Voltage vs. Output Current

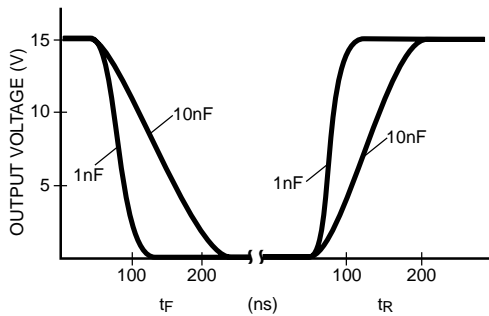


Figure 9. Output Rise/Fall Time

### Output Driver Stage

The ML4818 has four high current high speed totem pole output drivers each capable of 1.5A peak output, designed to quickly switch the gates of capacitive loads, such as power MOSFET transistors. Figure 8 illustrates the saturation characteristics of the output drive transistors shown in Figure 7. Typical rise and fall time characteristics of the output drivers are illustrated with capacitive loads of 1nF and 10nF in Figure 9.

### Current Limit, Fault Detection and Soft Start

Current limit is implemented when the current sensed on  $I_{LIM}$  reaches the 1V limit. At this point, the PWM cycle is terminated. The flip flop (Figure 10) turns on the current source to charge  $C_{RST}$  and remains on for the duration of the clock period. When  $C_{RST}$  has charged to 3.4V, a soft start reset occurs. The number of times the PWM cycle is terminated due to over-current is “remembered” on  $C_{RST}$ . Over time,  $C_{RST}$  is discharged by  $R_{RST}$  providing a measure of “forgetting” when the over-current condition no longer occurs. This integrating fault detection is useful in differentiation between short circuit and load surge conditions.

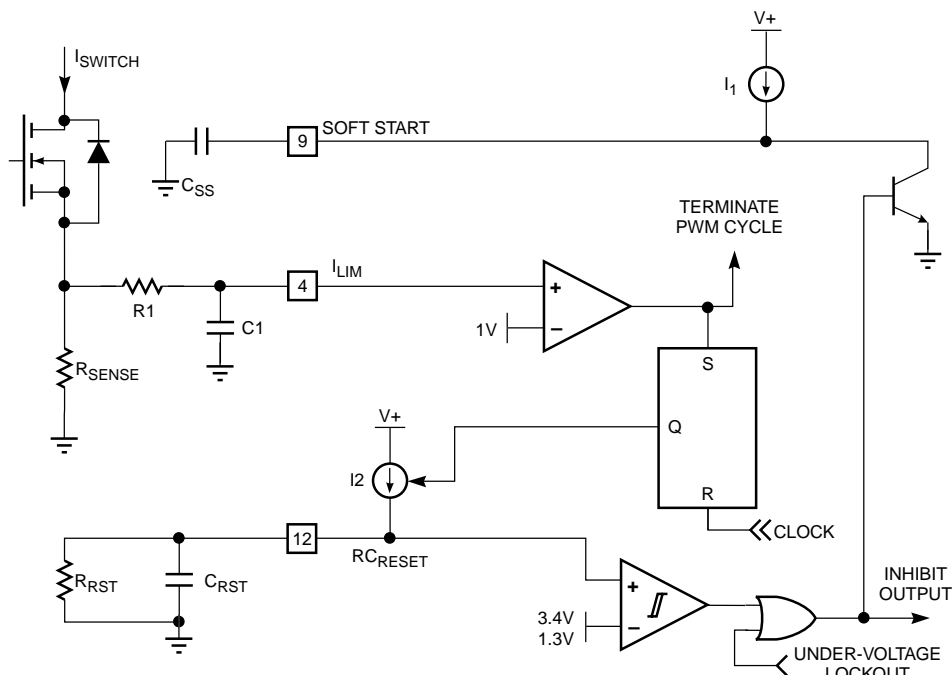


Figure 10. Over-Current, Soft-Start, and Integrating Fault Detect Circuits



Since the per cycle charge on  $RC_{RESET}$  is proportional to how early in the power cycle the over-current occurs, a reset will occur more quickly under output short circuit conditions (Figures 11a and 11b) than during a load surge (Figures 11c and 11d).

When the soft start reset occurs, the output is inhibited and the soft start capacitor is discharged. The output will remain off until  $C_{RST}$  discharges to 1.3V through  $R_{RST}$ , providing a reset delay. When the IC restarts, the error amplifier output voltage is limited to the voltage at SOFT START, thus limiting the duty cycle.

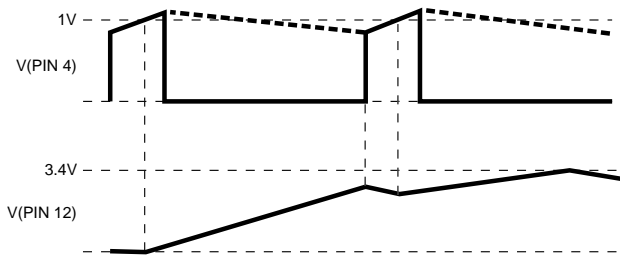


Figure 11a, 11b.  $I_{LIMIT}$  and Resulting  $RC_{RESET}$  Waveforms During Short Circuit

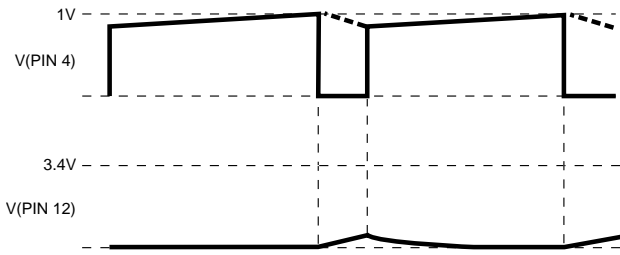


Figure 11c, 11d.  $I_{LIMIT}$  and Resulting  $RC_{RESET}$  Waveforms During Load Surge

### Under-Voltage Lockout

On power up, when  $V_{CC}$  is below 16V, the IC draws very little current (1.1mA typ.) and  $V_{REF}$  is disabled. When  $V_{CC}$  rises above 16V, the IC becomes active and  $V_{REF}$  is enabled and will stay in that condition until  $V_{CC}$  falls below 10.2V. (see Figure 12).

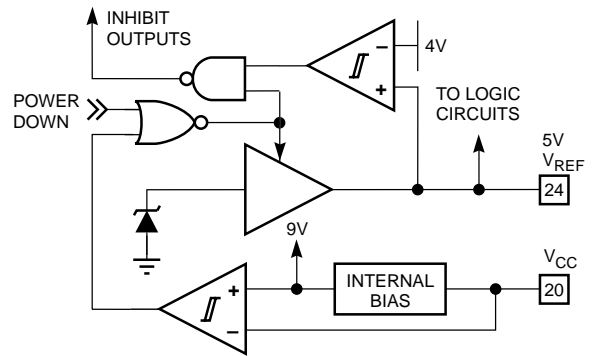


Figure 12. Under-Voltage Lockout and Reference Circuits

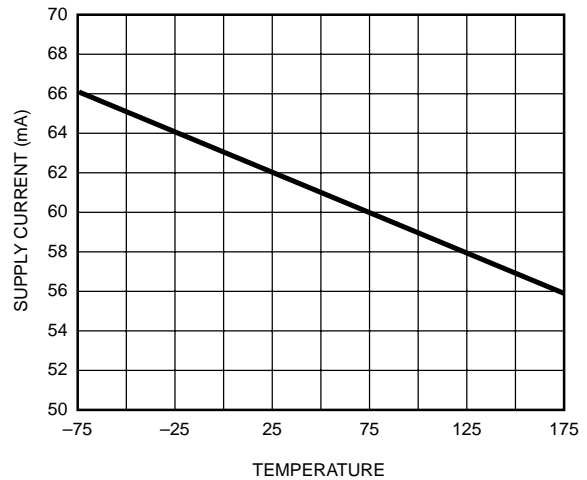


Figure 13. Supply Current vs. Temperature (°C)

## Thermal Information

The ML4818 is offered in a Power DIP package. This package features improved thermal conduction through the lead-frame. Much of the heat is conducted through the center 4 grounded leads. Thermal dissipation can be improved with this package by using copper area on the board to function as a heat sink. Increasing this area can reduce the  $\theta_{JA}$  (see figures 14 and 15), increasing the power handling capability of the package. Additional improvement may be obtained by using an external heat sink (available from Staver).

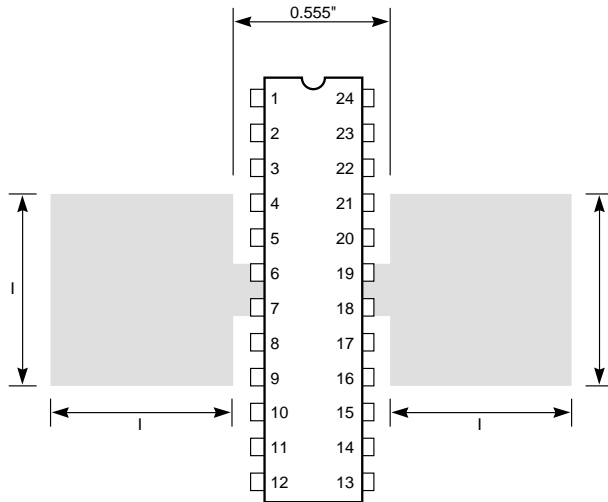


Figure 14. PC Board Copper Area Used as a Heat Sink

## Applications

The application circuit shown in Figure 16 features the ML4818 in a primary-side controlled voltage mode application with voltage feed-forward. Input voltage is rectified 120VAC (nominal). Feed-forward is provided by the RAMP pin via the resistor connected to the high voltage input. Current is sensed through sense transformer T4.

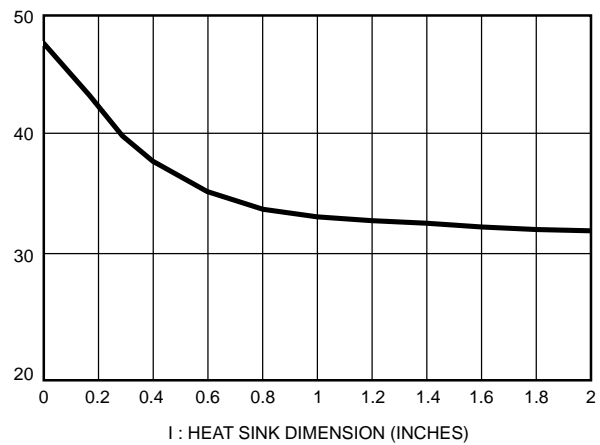


Figure 15.  $\theta_{JA}$  as a Function of  $l$  (see figure 15)

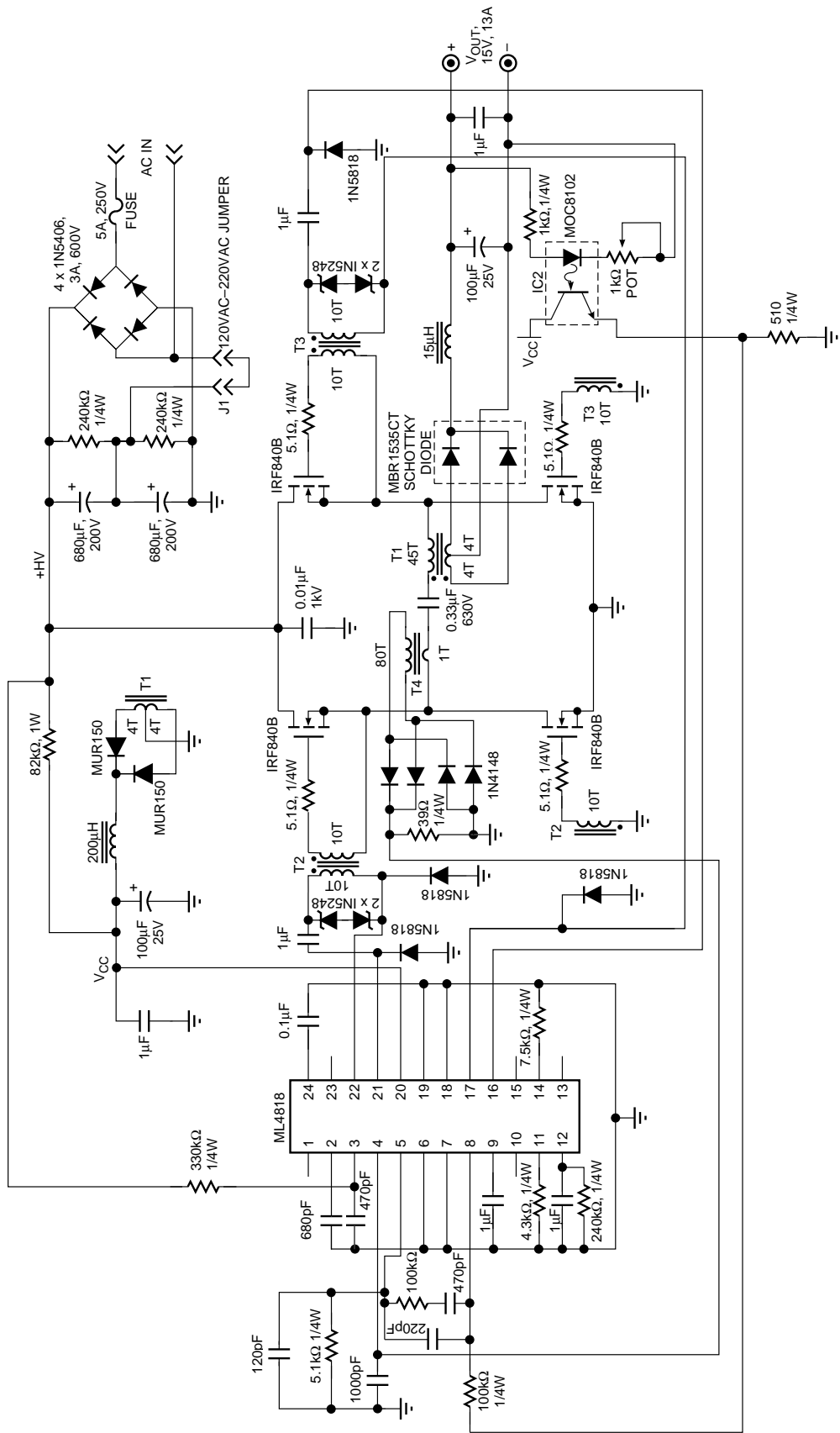
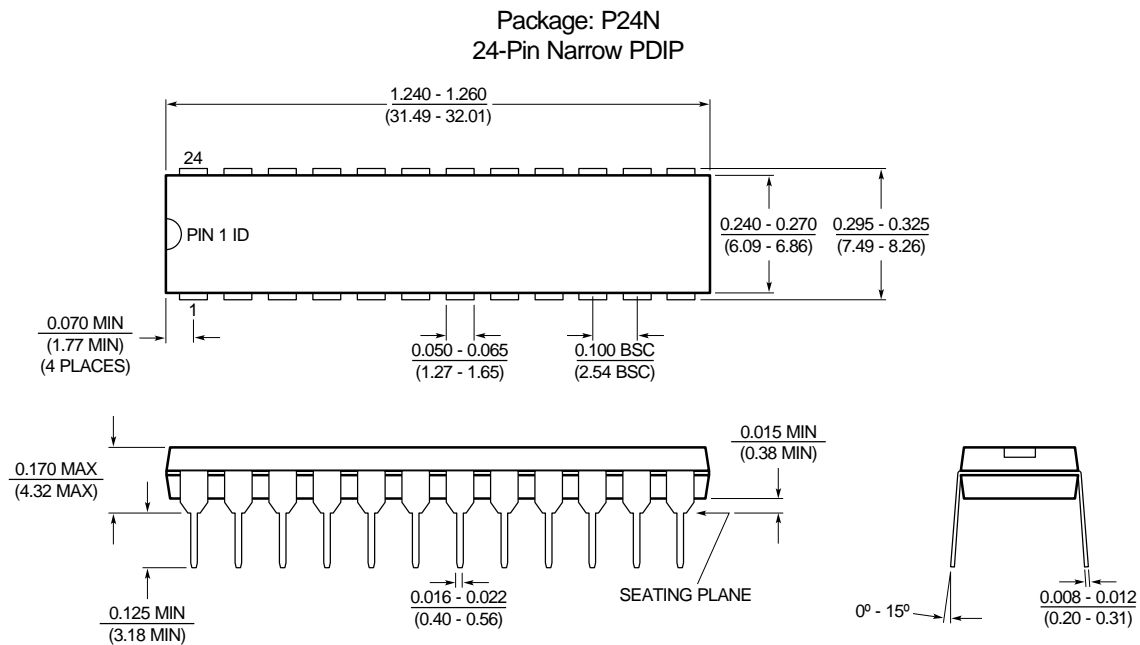


Figure 16. Offline Full Bridge Converter

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## Mechanical Dimensions inches (millimeters)



## Ordering Information

Part Number	Temperature Range	Package
ML4818CP	0°C to 70°C	Power DIP (P24)

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