

# High Frequency Power Supply Controller

## FEATURES

The ML4810 and ML4811 High Frequency PWM Controllers are optimized for use in Switch Mode Power Supply designs running at frequencies to 1MHz. The ML4810/11 contain a unique overload protection circuit which helps to limit stress on the output devices and reliably performs a soft-start reset. These controllers are designed to work in either voltage or current mode and provide for input voltage feed forward.

A 1.1V threshold current limit comparator provides a cycle-by-cycle current limit. An integrating circuit “counts” the number of times the 1.1V limit was reached. A soft-start cycle is initiated if the cycle-by-cycle current limit is repeatedly activated. A reset delay function is provided on the ML4811.

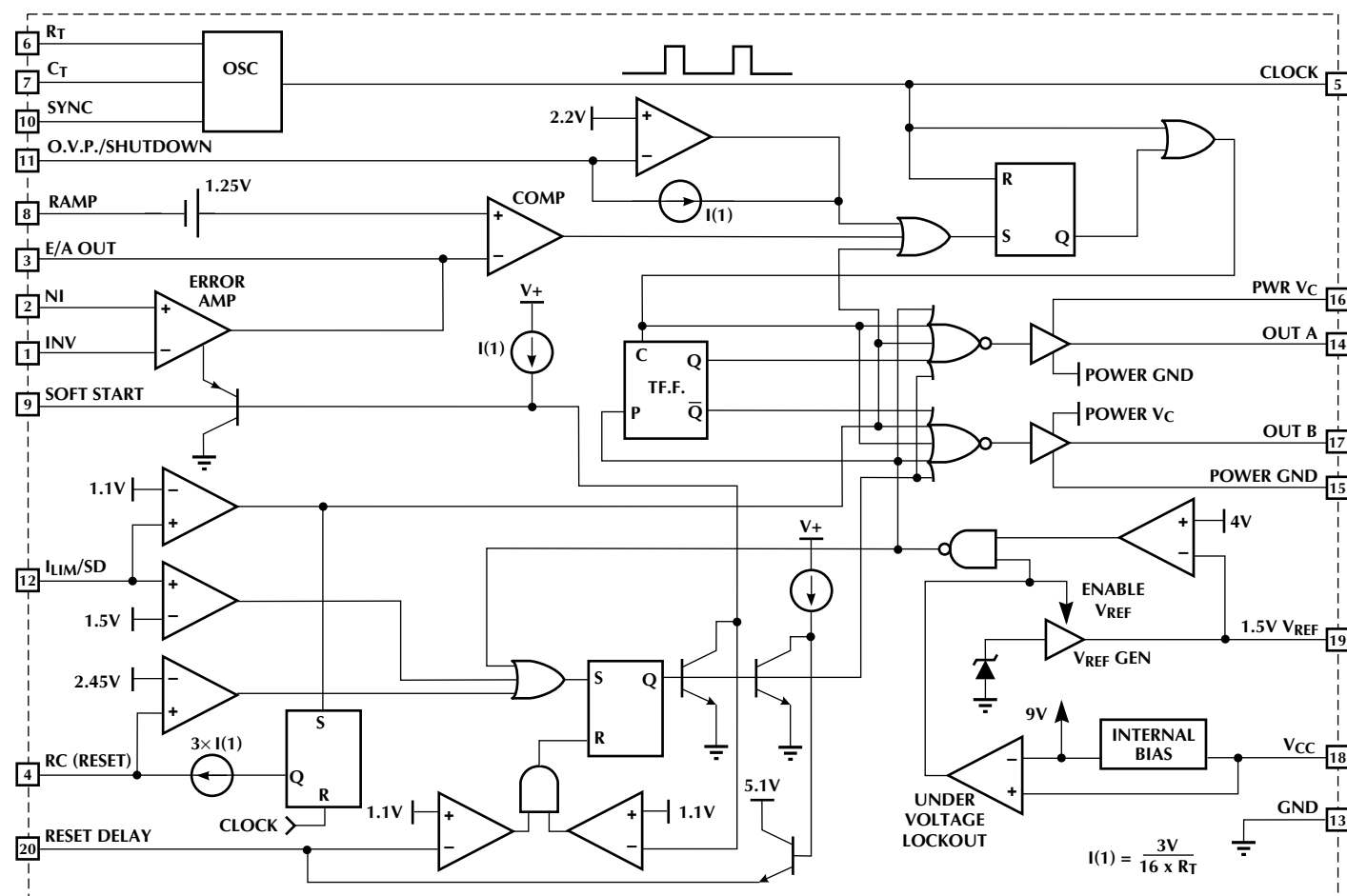
These controllers are similar to the UC1825 controller, however these controllers include many features not found on the 1825. These features are set in *Italics*.

- *Integrating Soft Start Reset*
- High current (2A peak) dual totem pole outputs
- Practical operation to 1MHz ( $f_{OSC}$ )
- 5.1V  $\pm$ 2% trimmed bandgap reference
- *Under voltage lockout with 7V hysteresis*
- *Soft Start Reset Delay (ML4811)*
- *Oscillator synchronization function (ML4811)*
- *Soft Start latch ensures full soft start cycle*
- *Outputs pull low for undervoltage lockout*
- *Accurately controlled oscillator ramp discharge current*
- *All timing currents "slaved" to  $R_T$  for precise control*

\* This part is End of Life as of August 1, 2000

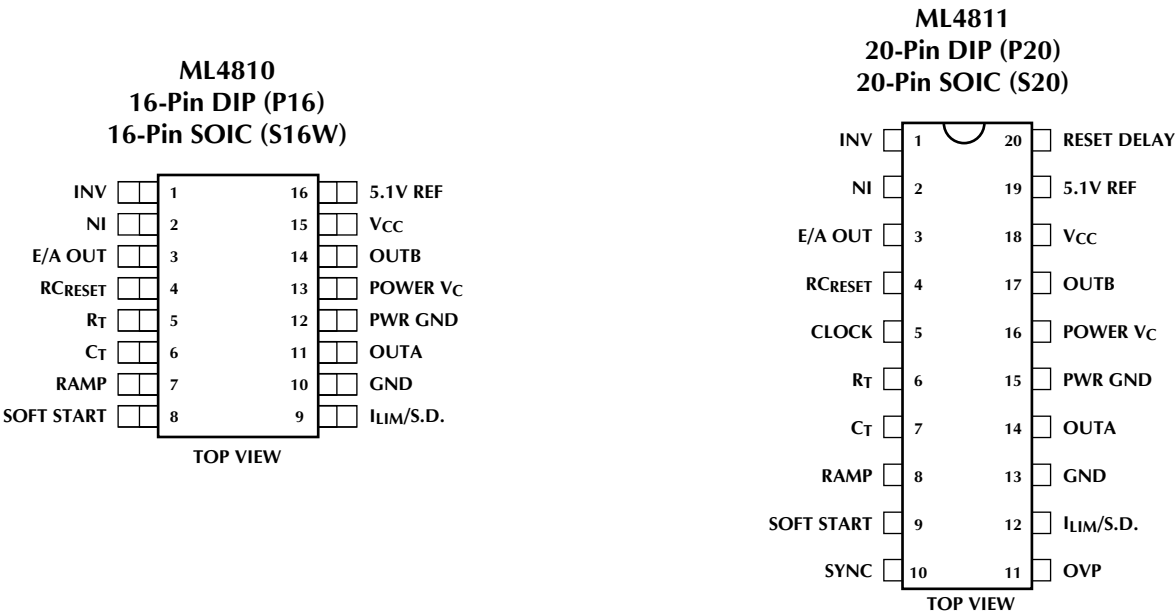
**\*\* This part is Obsolete**

### BLOCK DIAGRAM (Pin numbers shown are for ML4811)



# ML4810, ML4811

## PIN CONFIGURATION



## PIN DESCRIPTION

| PIN | NAME       | FUNCTION  | PIN | NAME        | FUNCTION   |
|-----|------------|---|-----|-------------|--|
| 1   | INV        | Inverting input to error amp.   | 11  | OVP         | Exceeding 2.5V terminates the PWM cycle and inhibits the outputs.                            |
| 2   | NI         | Non-inverting input to error amp.   | 12  | ILIM/S.D.   | Current limit sense pin. Normally connected to current sense resistor.                       |
| 3   | E/A OUT    | Output of error amplifier and input to main comparator.   | 13  | GND         | Analog signal ground.  |
| 4   | RCRESET    | Timing elements for Integrating Soft Start reset.   | 14  | OUTA        | High current totem pole output. This output is the first one energized after power on reset. |
| 5   | CLOCK      | Oscillator output.  | 15  | PWR GND     | Return for the high current totem pole outputs.  |
| 6   | RT         | Timing resistor for oscillator — sets charging current for oscillator timing capacitor (pin 6).                                   | 16  | VC          | Positive supply for the high current totem pole outputs.                                     |
| 7   | CT         | Timing capacitor for oscillator.  | 17  | OUTB        | High current totem pole output.  |
| 8   | RAMP       | Non-inverting input to main comparator. Connected to CT for voltage mode operation or to current sense resistor for current mode. | 18  | VCC         | Positive supply for the IC.  |
| 9   | SOFT START | Normally connected to Soft Start capacitor.   | 19  | 5.1V REF    | Buffered output for the 5.1V voltage reference.  |
| 10  | SYNC       | A high going pulse terminates the PWM cycle and discharges CT.  | 20  | RESET DELAY | Timing capacitor to determine the amount of delay between fault.                             |

## 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.

|  |             |
|--|-------------|
| Supply Voltage (Pins 18, 16) .....           | 25V         |
| Output Current, Source or Sink (Pins 14, 17) |             |
| DC .....                                     | 0.5A        |
| Pulse (0.5μs) .....                          | 2.0A        |
| Analog Inputs                                |             |
| (Pins INV, NI, SOFT START) .....             | -0.3V to 7V |
| (Pins 9, 10, 11, 12, 20) .....               | -0.3V to 6V |

|  |                |
|--|----------------|
| Clock Output Current (Pins 5) .....          | -5mA           |
| Error Amplifier Output Current (Pin 3) ..... | 5mA            |
| Junction Temperature .....                   | 150°C          |
| Storage Temperature Range .....              | -65°C to 150°C |
| Lead Temperature (Soldering 10 sec.) .....   | 260°C          |
| Thermal Resistance ( $\theta_{JA}$ )         |                |
| Plastic DIP .....                            | 65°C/W         |
| Plastic SOIC .....                           | 65°C/W         |

## OPERATING CONDITIONS

|                      |             |
|----------------------|-------------|
| Temperature Range    |             |
| ML4810, ML4811 ..... | 0°C to 70°C |

## ELECTRICAL CHARACTERISTICS

Unless otherwise specified,  $V_{CC} = 15V$ ,  $R_T = 3.65k\Omega$ ,  $C_T = 1000pF$ ,  $T_A =$  Operating Temperature Range. (Note 1)

| PARAMETER                   | CONDITIONS                       | MIN  | TYP  | MAX  | UNITS |
|-----------------------------|----------------------------------|------|------|------|-------|
| <b>OSCILLATOR</b>           |                                  |      |      |      |       |
| Initial Accuracy            | $T_J = 25^\circ C$               | 360  | 400  | 440  | kHz   |
| Voltage Stability           | $10V < V_{CC} < 25V$             |      | 0.2  | 4    | %     |
| Temperature Stability       |                                  |      | 5    |      | %     |
| Total Variation             | line, temperature                | 340  |      | 460  | kHz   |
| Clock Out High              |                                  | 3.9  | 4.5  |      | V     |
| Clock Out Low               |                                  |      | 2.3  | 2.9  | V     |
| Ramp Peak                   |                                  |      | 2.8  |      | V     |
| Ramp Valley                 |                                  |      | 1.0  |      | V     |
| Ramp Valley to Peak         |                                  | 1.6  |      | 2.3  | V     |
| Sync Input Threshold        |                                  | 0.8  | 1.0  | 1.4  | V     |
| Sync Input Current          | $SYNC = 4V$                      |      |      |      | μA    |
| <b>REFERENCE</b>            |                                  |      |      |      |       |
| Output Voltage              | $T_J = 25^\circ C$ , $I_O = 1mA$ | 5.00 | 5.10 | 5.20 | V     |
| Line Regulation             | $10V < V_{CC} < 25V$             |      | 2    | 20   | mV    |
| Load Regulation             | $1mA < I_O < 10mA$               |      | 5    | 20   | mV    |
| Temperature Stability       | $0^\circ C < T_J < 150^\circ C$  |      | 0.2  | 0.4  | %     |
| Total Variation             | line, load, temperature          | 4.95 |      | 5.25 | V     |
| Output Noise Voltage        | 10Hz to 10kHz                    |      | 50   |      | μV    |
| Long Term Stability         | $T_J = 125^\circ C$ , 1000 hrs   |      | 5    | 25   | mV    |
| Short Circuit Current       | $V_{REF} = 0V$                   | -15  | -50  | -100 | mA    |
| <b>UNDERVOLTAGE LOCKOUT</b> |                                  |      |      |      |       |
| Start Threshold             |                                  | 15   | 16   | 17   | V     |
| UVLO Hysteresis             |                                  | 6.5  | 7    | 7.5  | V     |
| <b>ERROR AMPLIFIER</b>      |                                  |      |      |      |       |
| Input Offset Voltage        |                                  |      |      | ±20  | mV    |
| Input Bias Current          |                                  |      | 0.6  | 3    | μA    |
| Input Offset Current        |                                  |      | 0.1  | 1    | μA    |
| Open Loop Gain              | $1 < V_O < 4V$                   | 60   | 96   |      | dB    |

# ML4810, ML4811

## ELECTRICAL CHARACTERISTICS (Continued)

| PARAMETER                       |        | CONDITIONS  | MIN  | TYP  | MAX  | UNITS |
|---------------------------------|--------|---|------|------|------|-------|
| ERROR AMPLIFIER (Continued)     |        |   |      |      |      |       |
| CMRR                            |        | $1.5 < V_{CM} < 5.5V$                                       | 65   | 95   |      | dB    |
| PSRR                            |        | $10 < V_{CC} < 30V$   | 75   | 90   |      | dB    |
| Output Sink Current             |        | $V_{PIN\ 3} = 1V$   | 1    | 2.5  |      | mA    |
| Output Source Current           |        | $V_{PIN\ 3} = 4V$   | −0.5 | −1.3 |      | mA    |
| Output High Voltage             |        | $I_{PIN\ 3} = −0.5mA$                                       | 4.0  | 4.7  | 5.0  | V     |
| Output Low Voltage              |        | $I_{PIN\ 3} = 1mA$  | 0    | 0.5  | 1.0  | V     |
| Unity Gain Bandwidth            |        |   | 3    | 5.5  |      | MHz   |
| Slew Rate                       |        |   | 6    | 12   |      | V/μs  |
| PWM COMPARATOR                  |        |   |      |      |      |       |
| Pin 8 Bias Current              |        | $V_{PIN\ 8} = 0V$   |      | −1   | −5   | μA    |
| Duty Cycle Range                |        |   | 0    |      | 75   | %     |
| Pin 3 Zero DC Threshold         |        |   | 1.1  | 1.25 |      | V     |
| Delay to Output                 |        |   |      | 50   | 80   | ns    |
| SOFT-START                      |        |   |      |      |      |       |
| Charge Current (Pin 9)          | ML4811 | $V_{PIN\ 9} = 1V, V_{PIN\ 4, 12} = 0$                       | −35  | −55  | −75  | μA    |
| Discharge Current (Pin 9)       |        | $V_{PIN\ 9} = 3V, V_{PIN\ 4} > 2.5$                         | 1    | 5    |      | mA    |
|                                 |        | $V_{PIN\ 9} = 3V, V_{PIN\ 12} > 1.65, V_{PIN\ 4} < 2$       | 1    | 5    |      | mA    |
| Charge Current (Pin 20)         |        | $V_{PIN\ 20} = 1V$  | 1    | 5    |      | mA    |
| Discharge Current (Pin 20)      |        | Requires external discharge resistor                        |      | 0    |      | μA    |
| CURRENT LIMIT/SHUTDOWN          |        |   |      |      |      |       |
| Pin 12 Bias Current             |        | $0V < V_{PIN\ 12} < 4V$                                     |      |      | +15  | μA    |
| Current Limit Threshold         | ML4810 |   | 1.2  | 1.3  | 1.4  | V     |
|                                 | ML4811 |   | 0.95 | 1.1  | 1.3  | V     |
| Reset Threshold (Pin 12)        | ML4810 | $V_{PIN\ 4} < 2V$   | 1.60 | 1.75 | 1.90 | V     |
|                                 | ML4811 | $V_{PIN\ 4} < 2V$   | 1.4  | 1.50 | 1.8  | V     |
| Delay to Output                 |        |   |      | 40   | 70   | ns    |
| Pin 4 Charging Current          |        | $V_{PIN\ 12} = 2V$  | 120  | 150  | 180  | μA    |
| Restart Threshold (Pin 4)       |        |   | 2    | 2.45 | 3    | V     |
| OVP Shutdown Threshold (Pin 11) |        |   | 2.4  | 2.7  | 2.8  | V     |
| OVP Input Current               |        | $V_{PIN\ 11} = 3V$  | 40   | 50   | 60   | μA    |
| Charge Current (Pin 8)          | ML4810 | $V_{PIN\ 8} = 1V, V_{PIN\ 4, 9} = 0$                        | −40  | −50  | −60  | μA    |
| OUTPUT                          |        |   |      |      |      |       |
| Output Low Level                |        | $I_{OUT} = 20mA$  |      | 0.25 | 0.4  | V     |
|                                 |        | $I_{OUT} = 200mA$   |      | 1.2  | 2.2  | V     |
| Output High Level               |        | $I_{OUT} = −20mA$   | 13.0 | 13.5 |      | V     |
|                                 |        | $I_{OUT} = −200mA$  | 12.0 | 13.0 |      | V     |
| Collector Leakage               |        | $V_C = 30V$   |      | 100  | 500  | μA    |
| Rise/Fall Time                  |        | $C_L = 1000pF$  |      | 30   | 60   | ns    |
| SUPPLY                          |        |   |      |      |      |       |
| Start Up Current                | ML4810 | $V_{CC} = 8V$   |      | 2.0  | 3.5  | mA    |
|                                 | ML4811 | $V_{CC} = 8V$   |      | 2.5  | 4.0  | mA    |
| $I_{CC}$                        | ML4810 | $V_{PIN\ 1, 7, 9} = 0V, V_{PIN\ 2} = 1V, T_A = 25^{\circ}C$ |      | 32   | 46   | mA    |
|                                 | ML4811 | $V_{PIN\ 1, 7, 9} = 0V, V_{PIN\ 2} = 1V, T_A = 25^{\circ}C$ |      | 38   | 55   | mA    |

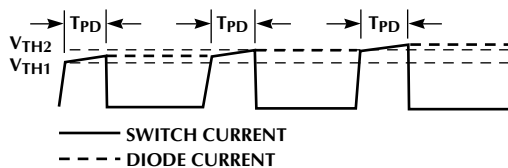
**Note 1:** Limits are guaranteed by 100% testing, sampling, or correlation with worst-case test conditions.

## FUNCTIONAL DESCRIPTION

## SOFT START AND CURRENT LIMIT

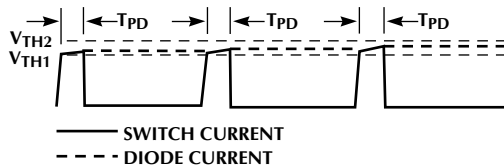
The ML4810/11 offers a unique system of fault detection and reset. Most PWM controllers use a two threshold method which relies on the buildup of current in the output inductor during a fault. This buildup occurs because:

1. Inductor  $di/dt$  is a small number when the switch is off under load fault (short circuit) conditions, since  $V_L$  is small.
2. Some energy is delivered to the inductor since the IC must first detect the over-current because there is a finite delay before the output switch can turn off.



### Figure 1. Current Waveforms for Slow Turn-Off System with Load Fault

This scheme was adequate for controllers with longer comparator propagation delays and turn-off delays than is desirable in a high frequency system. For systems with low propagation delays, very little energy will be delivered to the inductor and the current "ratcheting" described above will not occur. This results in the controller never detecting the load fault and continuing to pump full current to the load indefinitely, causing heating in the output rectifiers and inductor.

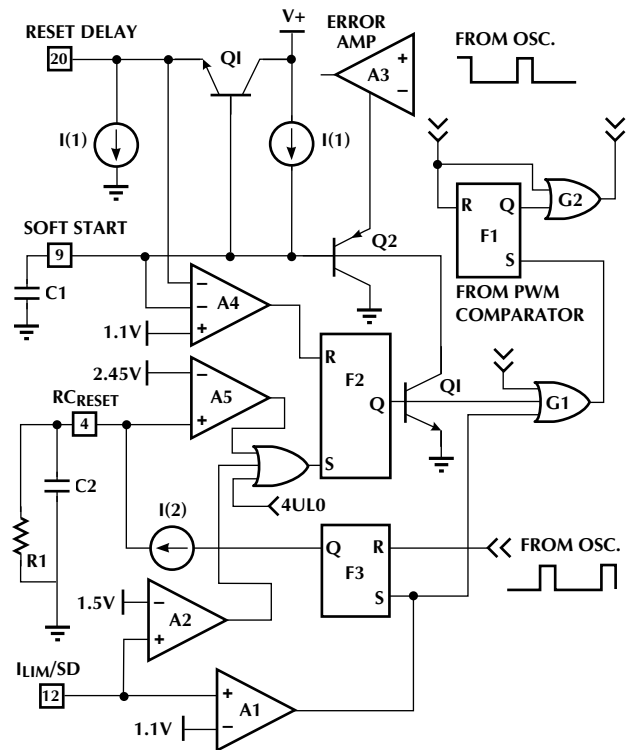


**Figure 2. Current Waveforms for High Speed System with Load Fault**

A method of circumventing this problem involves "counting" the number of times the controller terminates the PWM cycle due to the cycle by cycle current limit.

When the switch current crosses the 1.1V threshold A1 signals the F1 to terminate the cycle and sets F3, which is reset at the beginning of the PWM cycle. The output of F3 turns on a current source to charge C2. When, after several cycles, C2 has charged to 2.45V, A5 turns on F2 to discharge soft start capacitor C1. Charge is short lived (for instance a disk drive start-up or a board being plugged into a live rack) the control can “ride out” the surge with the switch protected by the cycle by cycle limit. R1 and C1 can be selected to track diode heating, or to ride out various system surge requirements as required.

If the high current demand is caused by a short circuit, the duty cycle will be short and the output diodes will carry the current for the majority of PWM cycle. C2 charges fastest for low duty cycles (since F3 will be on for a longer time) providing for quicker shutdown during short-circuit when the output diodes are being maximally stressed.



### Figure 3. Integrating Soft Start Reset

## OSCILLATOR

The ML4811 oscillator charges the external capacitor ( $C_T$ ) with a current ( $I_{SET}$ ) equal to  $3/R_T$ . When the capacitor voltage reaches the upper threshold (Ramp Peak), the comparator changes state and the capacitor discharges to the lower threshold (Ramp Valley) through Q1. While the capacitor is discharging, Q2 provides a high pulse. A discharge of the oscillator can be initiated by applying a high level to the Sync pin. A short pulse of a frequency higher than the oscillator's free running frequency can be used to synchronize the ML4811 to an external clock. The pulse can be equal to the desired deadtime ( $T_D$ ) or the deadtime can be determined by  $I_{DIS}$  and  $C_T$ , whichever is greater.

The oscillator period can be described by the following relationship:

$$t_{OSC} = t_{RAMP} + t_{DEADTIME}$$

where:

$$t_{RAMP} = \frac{C (Ramp Valley to Peak)}{I_{SET}}$$

and:

$$t_{DEADTIME} = \frac{C (Ramp Valley to Peak)}{I_{Q1}}$$

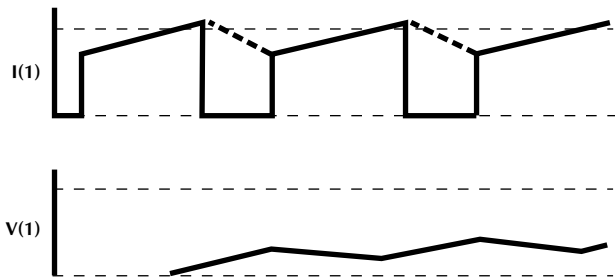


Figure 4. Switching Current and Pin 4 Voltage — Normal

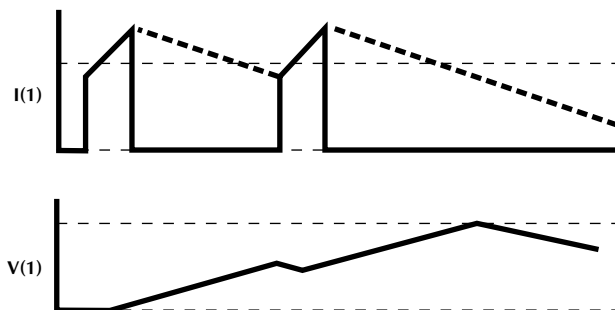


Figure 5. Switching Current and Pin 4 Voltage — Load Fault

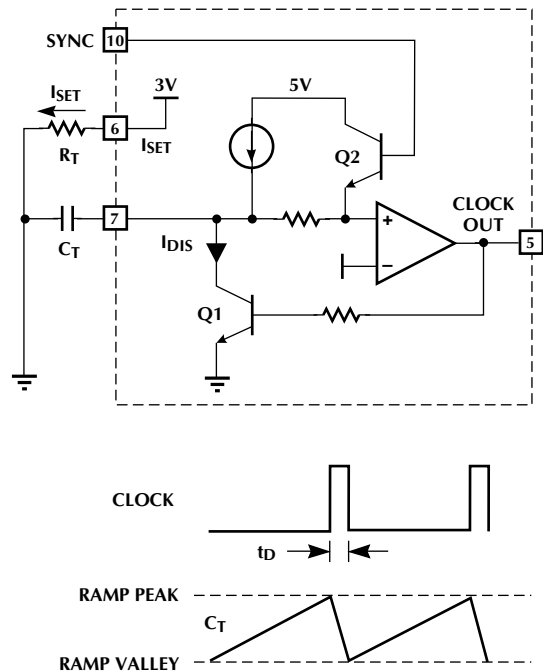


Figure 6. Simplified Oscillator Block Diagram and Timing

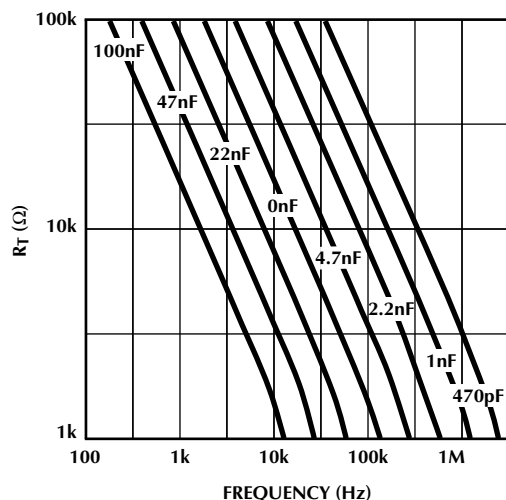


Figure 7. Oscillator Timing Resistance vs Frequency

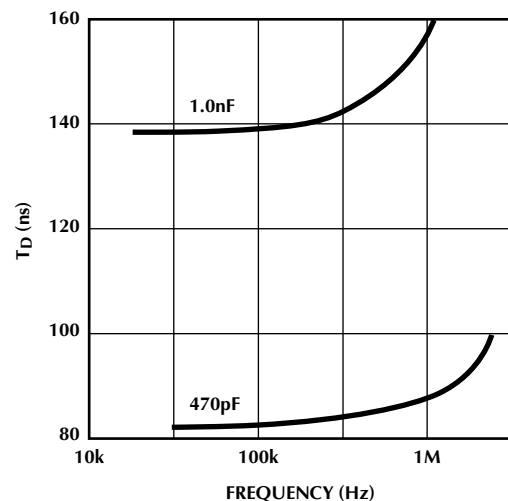


Figure 8. Oscillator Deadtime vs Frequency

## ERROR AMPLIFIER

The ML4811 error amplifier is a 5.5MHz bandwidth 12V/ $\mu$ sec slew rate op-amp with provision for limiting the positive output voltage swing (Output Inhibit line) for ease in implementing the soft start function.

## OUTPUT DRIVER STAGE

The ML4811 Output Driver is a 2A peak output high speed totem pole circuit designed to quickly switch the gates of capacitive loads, such as power MOSFET transistors.

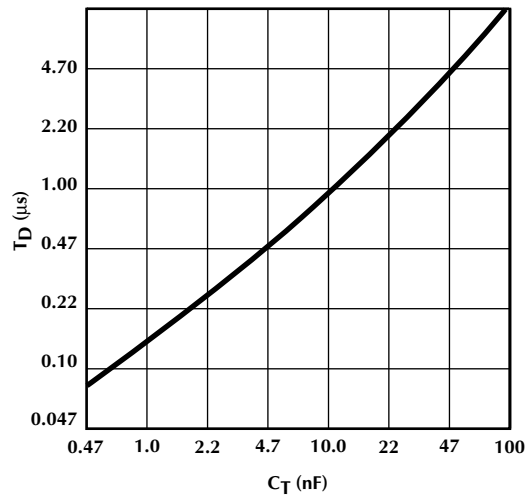


Figure 9. Oscillator Deadtime vs  $C_T$  ( $3k\Omega \leq R_T \leq 100k\Omega$ )

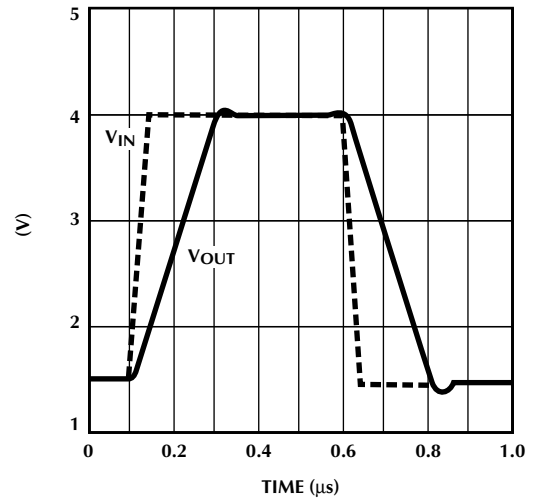


Figure 10. Unity Gain Slew Rate

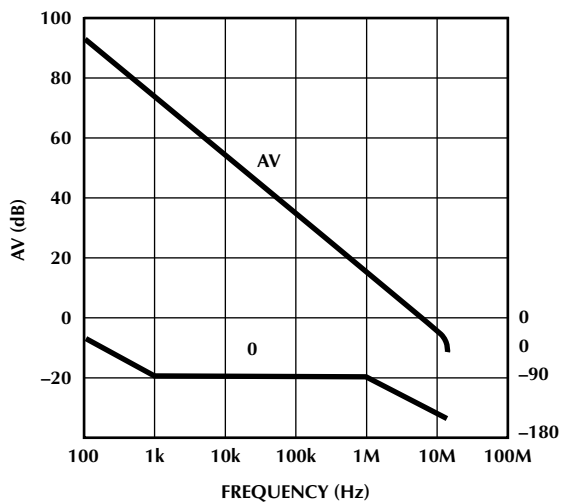


Figure 11. Open Loop Frequency Response

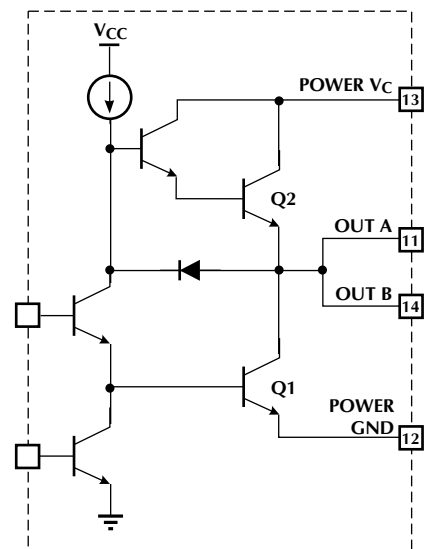


Figure 12. Simplified Schematic

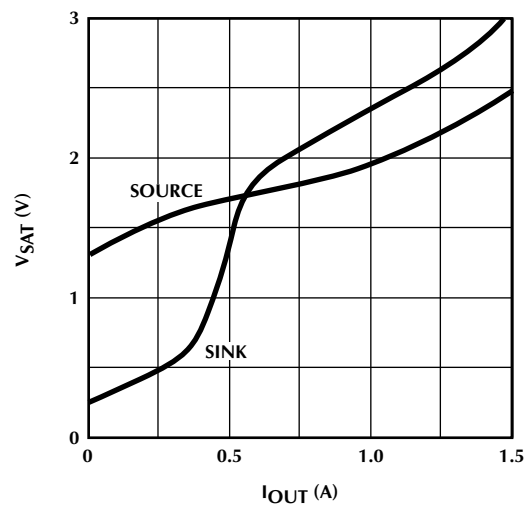


Figure 13. Saturation Curves

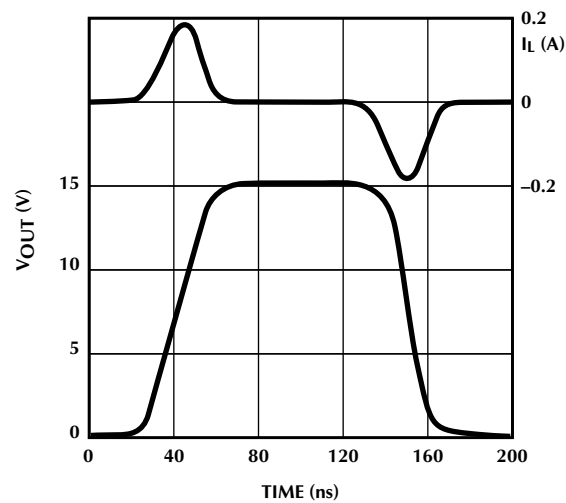


Figure 14. Rise/Fall Time ( $C_L = 1000pF$ )

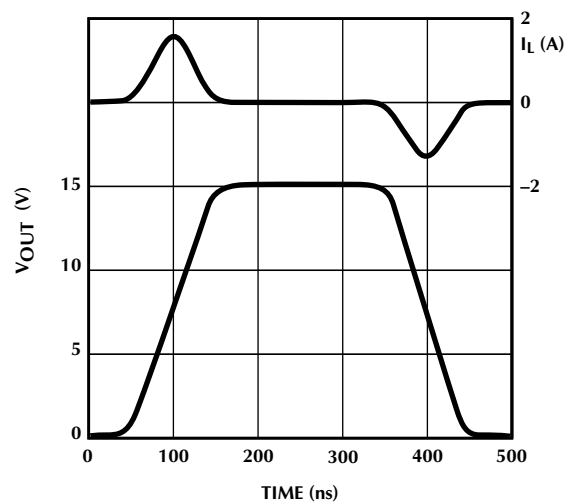


Figure 15. Rise/Fall Time ( $C_L = 10,000pF$ )

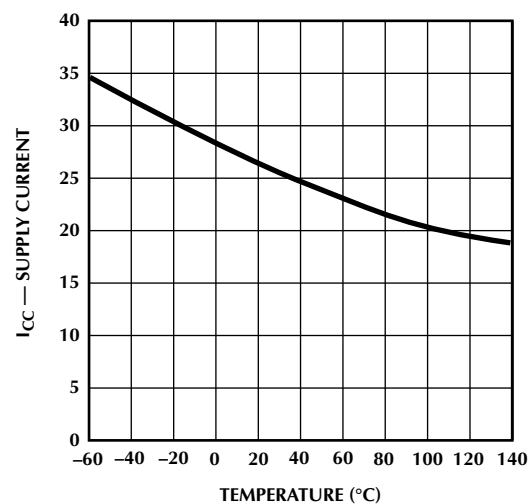


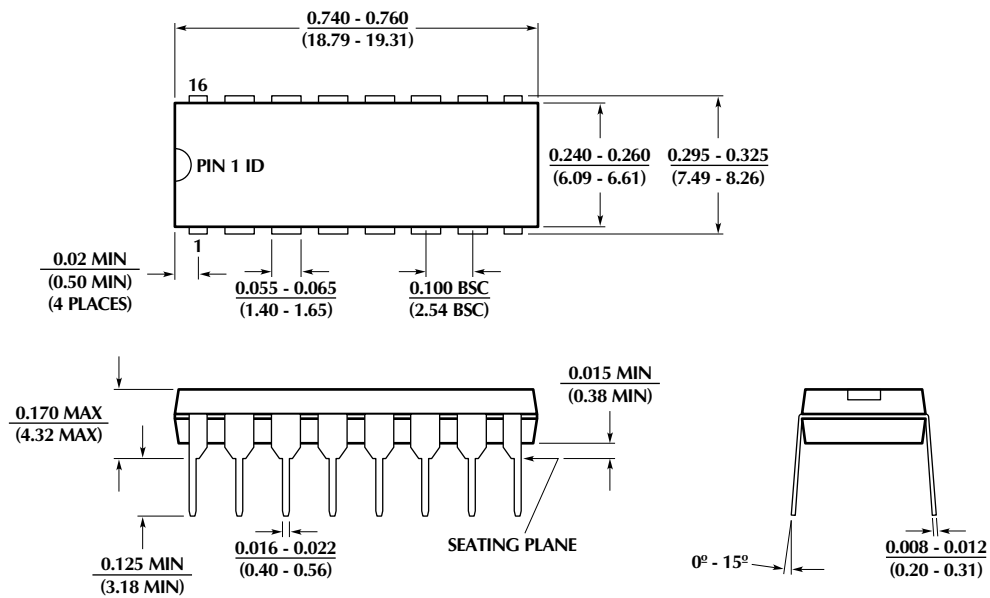
Figure16. Supply Current vs. Temperature



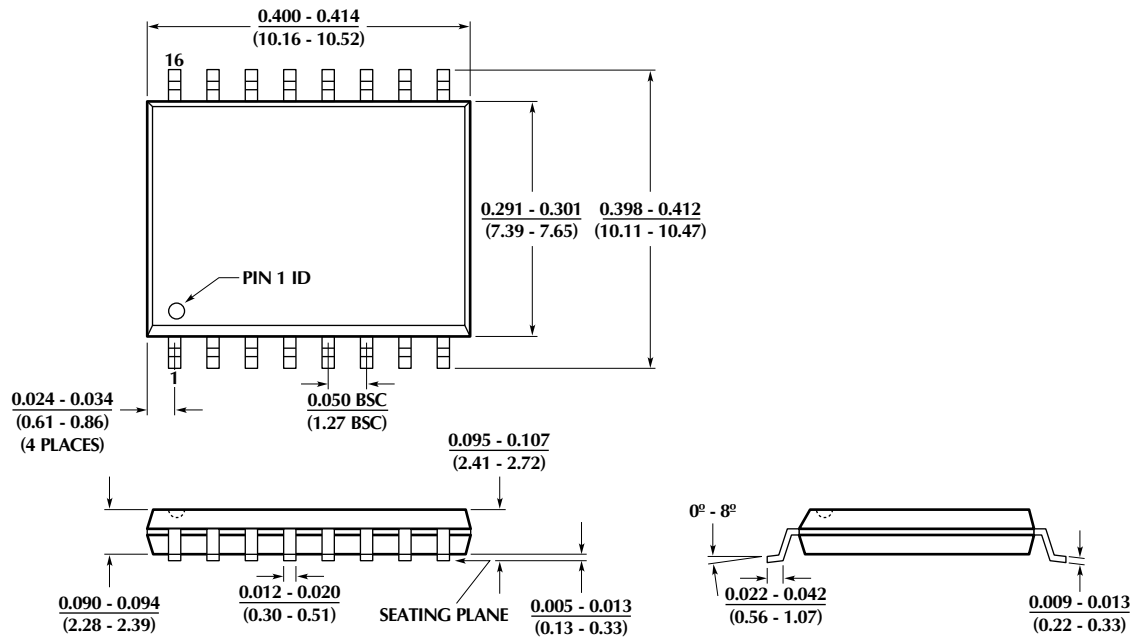


## PHYSICAL DIMENSIONS inches (millimeters)

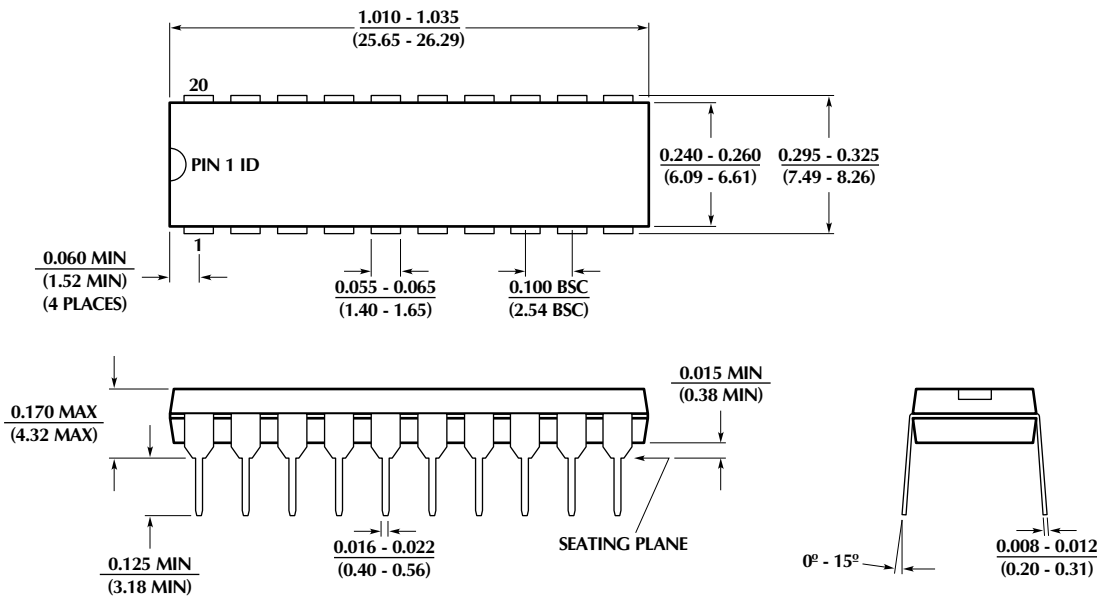
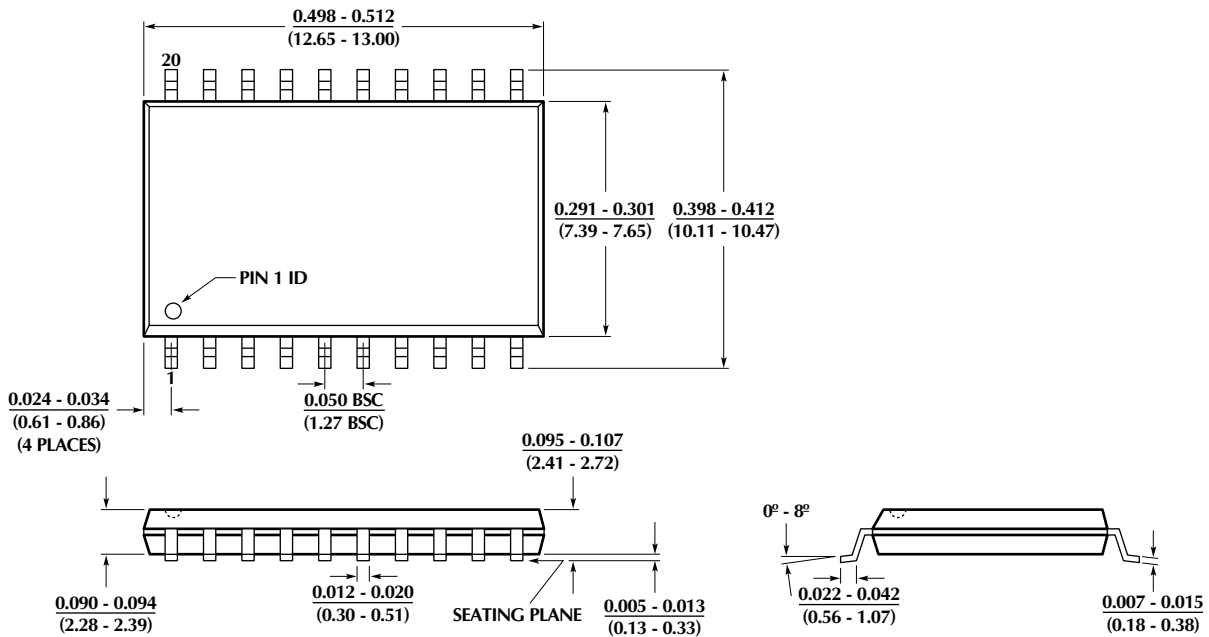
Package: P16  
16-Pin PDIP



Package: S16W  
16-Pin Wide SOIC




## PHYSICAL DIMENSIONS inches (millimeters) (Continued)

Package: P20  
20-Pin PDIPPackage: S20  
20-Pin SOIC

## ORDERING INFORMATION

| PART NUMBER | TEMPERATURE RANGE | PACKAGE                            |
|-------------|-------------------|------------------------------------|
| ML4810CP    | 0°C to 70°C       | 16-Pin PDIP (P16) (End Of Life)    |
| ML4810CS    | 0°C to 70°C       | 16-Pin Wide SOIC (S16W) (Obsolete) |
| ML4811CP    | 0°C to 70°C       | 20-Pin PDIP (P20) (Obsolete)       |
| ML4811CS    | 0°C to 70°C       | 20-Pin SOIC (S20)(Obsolete)        |

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Products described in this document may be covered by one or more of the following patents, U.S.: 4,897,611; 4,964,026; 5,027,116; 5,281,862; 5,283,483; 5,418,502; 5,508,570; 5,510,727; 5,523,940; 5,546,017; 5,559,470; 5,565,761; 5,592,128; 5,594,376; Japan: 2598946; 2619299. Other patents are pending.

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