# EST.384xB/BS
# High Performance Current Mode Controller

The EST.384xB series are high performance fixed frequency current mode controllers. They are specifically designed for off-line and AC-to-DC converter applications offering the designer a cost effective solution with minimal external components. These integrated circuits feature a trimmed oscillator for precise duty cycle control, a temperature compensated reference, high gain error amplifier,current sensing comparator, and a high current totem pole output ideally suited for driving a power MOSFET.

Also included are protective features consisting of input and reference undervoltage lockouts each with hysteresis, cycle-by-cycle current limiting, programmable output deadtime, and a latch for single pulse metering.

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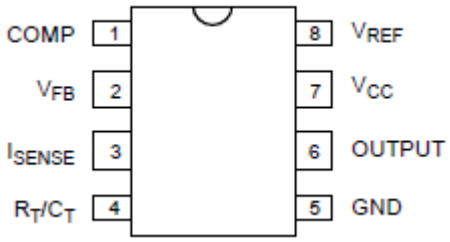
## FEATURES

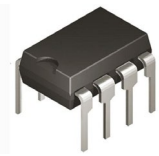
- Trimmed Oscillator Discharge Current for Precise Duty Cycle Control
- Current Mode Operation to 500KHz
- Automatic Feed Forward Compensation
- Latching PWM for Cycle-By-Cycle Current Limiting
- Internally Trimmed Reference with Under voltage Lockout
- High Current Totem Pole Output(1A)
- Under voltage Lockout with Hysteresis
- Low Start-Up and Operating Current

## PIN ARRANGEMENT





SOP-8L

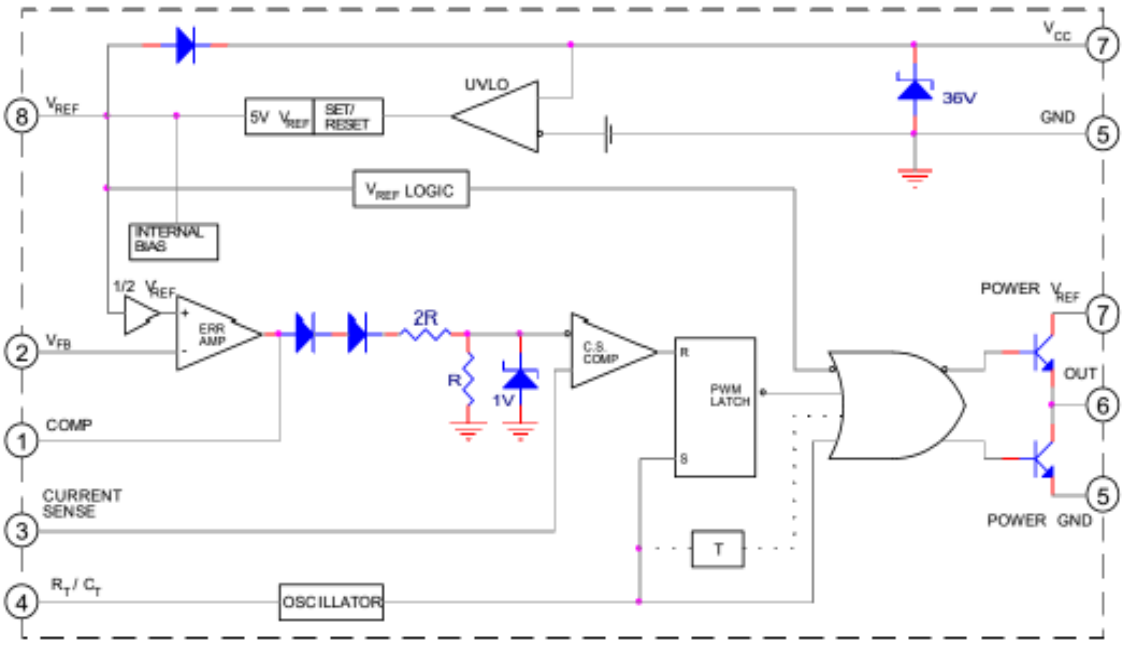


DIP-8L

## ORDERING INFORMATION

| Device | Top Marking | Package | Packaging | Note |
|---|---|---|---|---|
| EST.3842/43/44/45 | EST.3842B/43B/44B/45B | DIP-8 | Tube | Green Package |
| EST.3842/43/44/45BS | EST.3842BS/43BS/44BS/45BS | SOP-8 | Tape | Green Package |
| EST.3842/43/44/45BSR | EST.3842BS/43BS/44BS/45BS | SOP-8 | Reel | Green Package |

## BLOCK DIAGRAM




## ABSOLUTE MAXIMUM RATING

| Rating | Symbol | Value | Unit |
|---|---|---|---|
| Total Power Supply | $V_{CC}$ | 30 | V |
| Output Current Source or Sink (Note 1) | Io | 1.0 | A |
| Output Energy (Capacitive Load per Cycle) | W | 5.0 | μJ |
| Current Sense and Voltage Feedback Inputs | Vin | -0.3 to 6.3 | V |
| Error Amp Output Sink Current | Io | 10 | mA |
| Power Dissipation and Thermal Characteristics | | | |
| SOP-8 | | | |
| Maximum Power Dissipation @ $T_A$=25℃ | $P_D$ | 460 | mW |
| Thermal Resistance Junction to Air | $R_{\Theta JA}$ | 160 | ℃/W |
| DIP-8 | | | |
| Maximum Power Dissipation @ $T_A$=25℃ | $P_D$ | 1.00 | W |
| Thermal Resistance Junction to Air | $R_{\Theta JA}$ | 140 | ℃/W |
| Operating Junction Temperature | $T_J$ | -40 to 150 | ℃ |
| Operating Ambient Temperature | $T_A$ | 0 to 70 | ℃ |
| Storage Temperature Range | Tstg | -55 to +150 | ℃ |

## ELECTRICAL CHARACTERISTICS

(Vcc=15V, RT=10KΩ, CT=3.3nF, TA=Tlow to Thigh unless otherwise noted).

| Characteristic | Symbol | Limit Values | | | Unit |
|---|---|---|---|---|---|
| | | Min | Typ | Max | |
| **Reference Section** | | | | | |
| Reference Output Voltage (Io=1.0mA,TJ=25℃) | $V_{ref}$ | 4.90 | 5.00 | 5.10 | V |
| Line Regulation (Vcc=12V to 25V) | $R_{egline}$ | -- | 6.0 | 20 | mV |
| Load Regulation (Io=1.0mA to 20mA) | $R_{egload}$ | -- | 6.0 | 25 | mV |
| Temperature Stability | Ts | -- | 0.30 | -- | mV/℃ |
| Output Noise Voltage (f=10Hz~10KHz,TJ=25℃) | Vn | -- | 50 | -- | μV |
| Long Term Stability (TA=125℃for 1000 Hours) | S | -- | 5.0 | -- | mV |
| Output Short Circuit Current | Isc | -30 | -80 | -180 | mA |
| **Oscillator Section** | | | | | |
| Frequency<br>TJ=25℃<br>TA=Tlow to Thigh | fosc | <br>47<br>46 | <br>52<br>- | <br>57<br>60 | KHz |
| Frequency Change with Voltage Vcc=12V to 25V | $\Delta_{fosc/\Delta V}$ | -- | 0.05 | 1.0 | % |
| Frequency Change with Temperature TA=Tlow to Thigh | $\Delta_{fosc/\Delta T}$ | -- | 5.0 | -- | % |
| Oscillator Voltage Swing (Peak-to-Peak) | $V_{osc}$ | -- | 1.6 | -- | Vpp |
| **Error Amplifier Section** | | | | | |
| Voltage Feedback Input (Vo=2.5V) | $V_{FB}$ | 2.42 | 2.50 | 2.58 | V |
| Input Bias Current (VFB=2.7V) | $I_{IB}$ | -- | -0.1 | -2.0 | μA |
| Open-Loop Voltage Gain (Vo=2.0V to 4.0V) | $A_{VOL}$ | 60 | 90 | -- | dB |
| Power Supply Rejection Radio (Vcc=12V to 25V) | $P_{SRR}$ | 60 | 70 | -- | dB |
| Output Current<br>Sink (Vo=1.1V, VFB=2.7V)<br>Source (Vo=5.0V, VFB=2.3V) | <br>Isink<br>ISource | <br>2.0<br>-0.5 | <br>6.5<br>-0.9 | <br>-- | mA |
| Output Voltage Swing<br>High State (RL=15KΩ to ground, $V_{FB}$=2.3V)<br>Low State (RL=15KΩ to Vref, $V_{FB}$=2.7V) | <br>$V_{OH}$<br>$V_{OL}$ | <br>5.0<br>- | <br>6.4<br>0.87 | <br>-<br>1.1 | V |
| **Current Sense Section** | | | | | |
| Current Sense Input Voltage Gain (Note 4&5) | Av | 2.85 | 3.0 | 3.15 | V/V |
| Maximum Current Sense Input Threshold (Note 4) | Vth | 0.9 | 1.0 | 1.1 | V |
| Power Supply Rejection Radio Vcc=12V to 25V | $P_{SRR}$ | - | 70 | - | dB |
| Input Bias Current | IIB | - | -2.0 | -10 | μA |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Output Section** | | | | | | |
| Output Voltage Low State | (Isink=20mA) | VOL | - | 0.1 | 0.4 | V |
| | (Isink=200mA) | | - | 1.5 | 2.2 | |
| Output Voltage High State | (Isource=20mA) | VOH | 13 | 13.5 | - | V |
| | (Isource=200mA) | | 12 | 13.0 | - | |
| Output Voltage with UVLO Activated Vcc=6.0V, Isink=1.0mA | | $V_{OL}(U_{VLO})$ | - | 0.1 | 1.1 | V |
| Output Voltage Rise Time ($C_L$=1.0nF, $T_J$=25℃) | | tr | - | 50 | 150 | ns |
| Output Voltage Fall Time ($C_L$=1.0nF, $T_J$=25℃) | | tf | | 50 | 150 | ns |
| **Undervoltage Lockout Section** | | | | | | |
| Start-Up Threshold | 3842B/3843B | Vth | 14.5 | 16.0 | 17.5 | V |
| | 3843B/3845B | | 7.8 | 8.3 | 9.0 | |
| Minimum Operating Voltage After Turn-On | 3842B/3843B | $V_{cc(min)}$ | 8.5 | 10.0 | 11.5 | V |
| | 3843B/3845B | | 7.0 | 7.6 | 8.2 | |
| **PWM Section** | | | | | | |
| Duty Cycle | 3842B/3843B | DCmax | 94 | 96 | -- | % |
| | 3843B/3845B | | 45 | 48 | 50 | |
| | | DCmin | -- | -- | 0 | |
| **Total Device** | | | | | | |
| Start-Up Current | 3842B/3843B | IST | - | 260 | 500 | uA |
| | 3843B/3845B | | - | 130 | 500 | |
| Operating Supply Current ($V_{FB}$=Vsense=0) | | ICC | - | 11 | 17 | mA |
| Power Supply Zener Voltage (Icc=25mA) | | Vz | 30 | 34 | - | V |

Note：1. Maximum Package power dissipation limits must be observed.

2. Adjust Vcc above the Start-Up threshold before setting to 15V.

3. Low duty cycle pulse techniques are used during EST.3842B to maintain junction temperature as close to ambient as possible.Tlow=0℃ for EST.3842B Thigh=+70℃ for EST. 3842B

4. This parameter is measured at the latch trip point with $V_{FB}$=0V.

5. Comparator gain is defined as：

$$Av=\frac{\Delta V \text{ Output Compensation}}{\Delta V \text{ Output Sense Input}}$$

## APPLICATION EXAMPLES

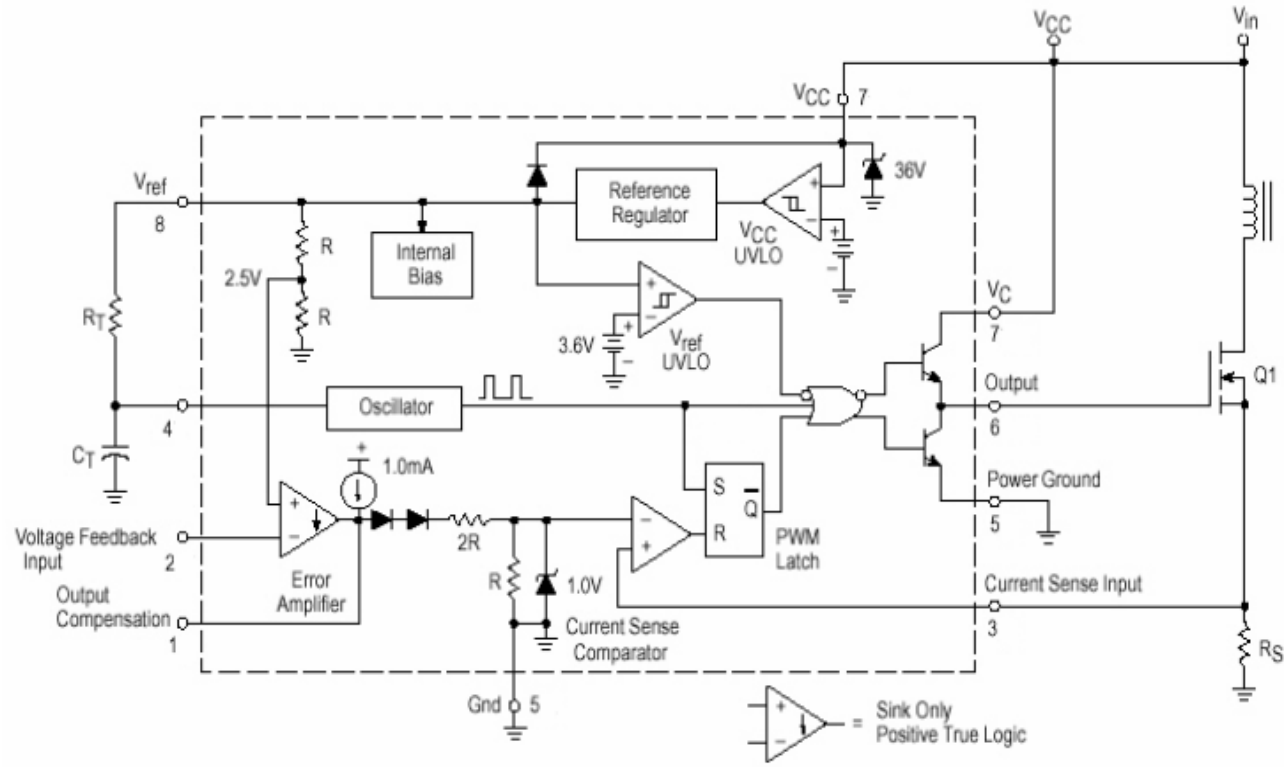



**Fig 1.Representative Block Diagram**

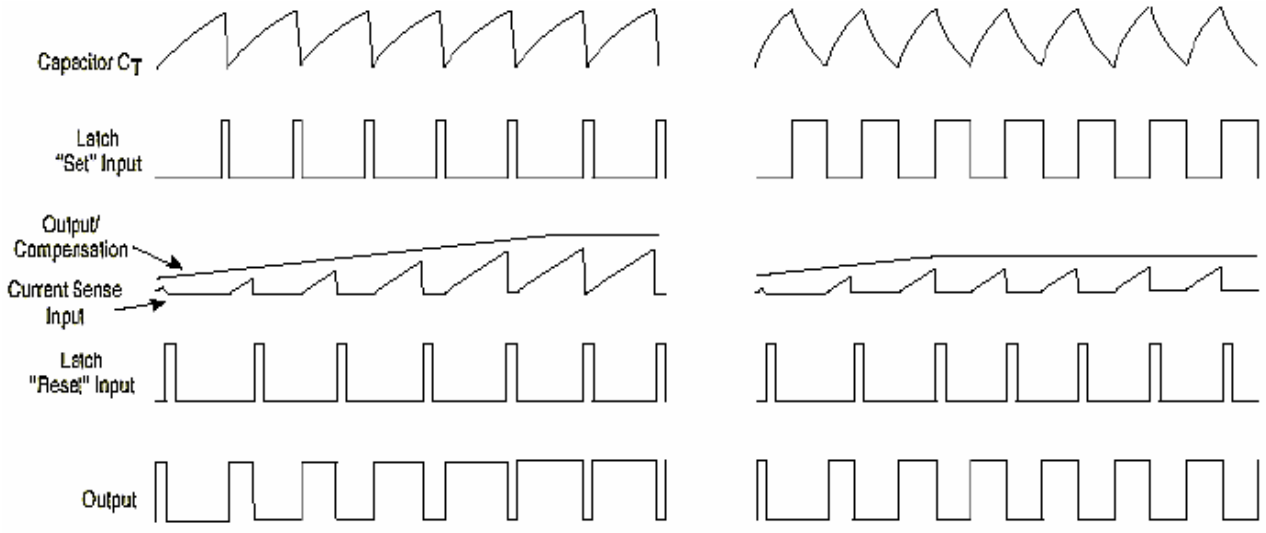
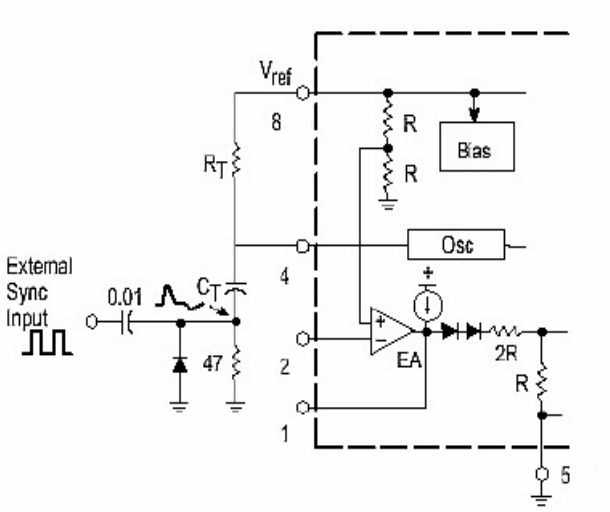
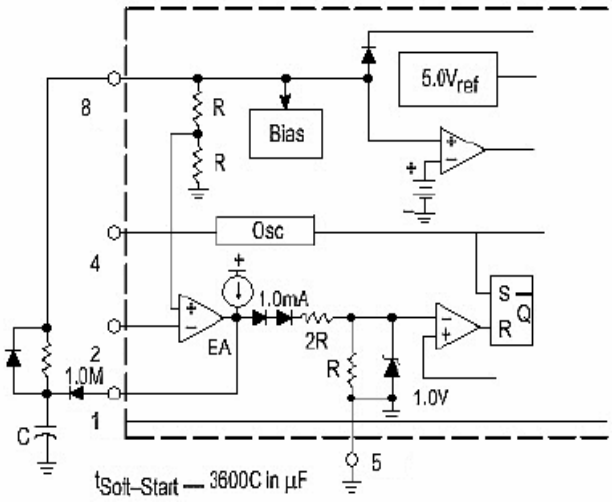



**Fig 2.Timing Diagram**

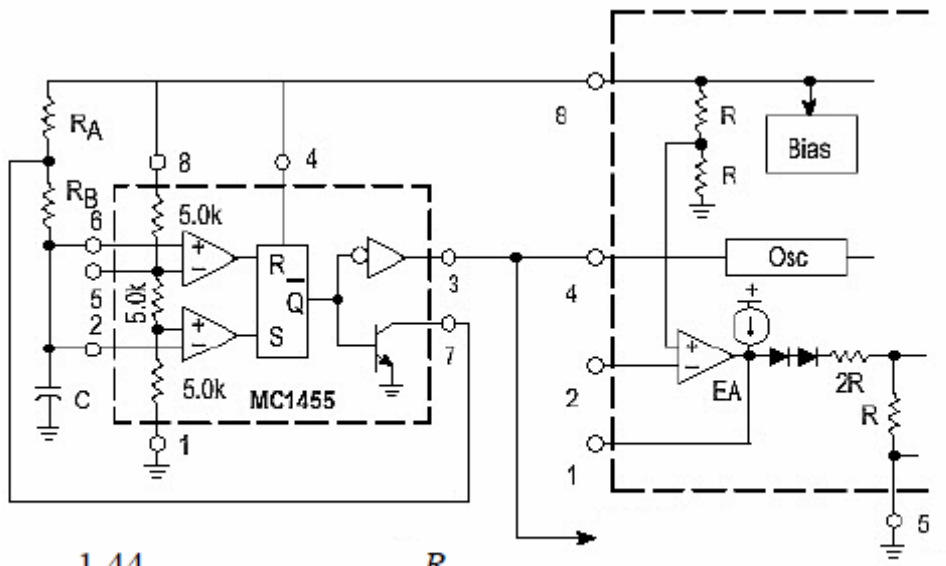



The diode clamp is required if the Sync amplitude is large enough to cause the bottom side of CT to go more than 300 mV below ground.

**Fig 3.External Clock Synchronization**

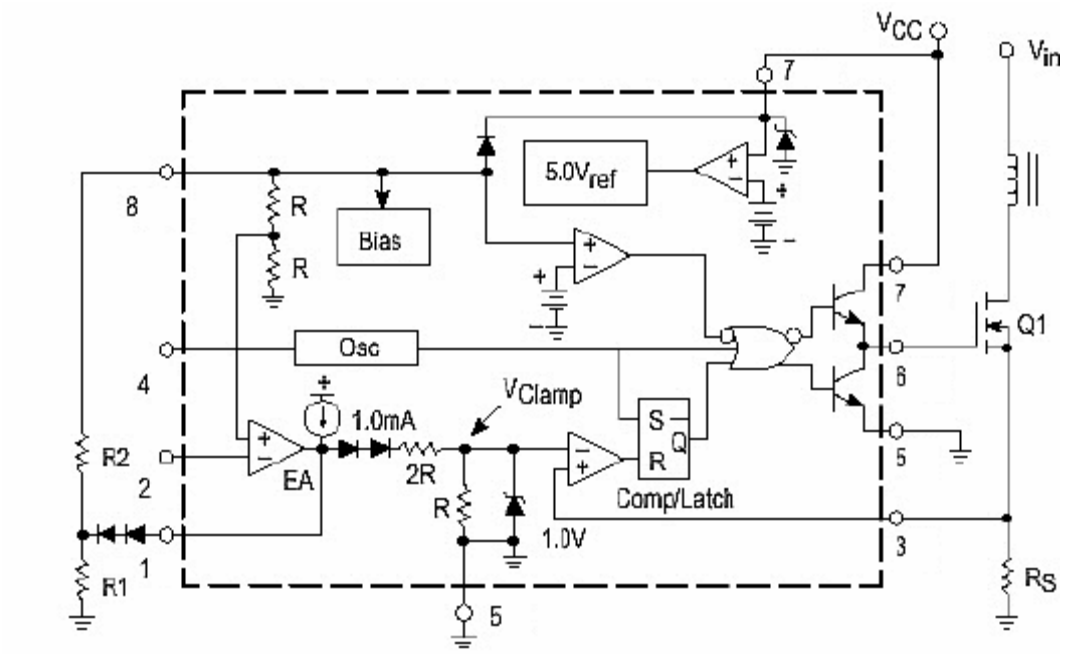
**Fig 4.Soft-Start Circuit**




$$f=\frac{1.44}{(R_A+2R_B)C} \qquad D_{max}=\frac{R_B}{R_A+2R_B}$$

TO Additional 384x

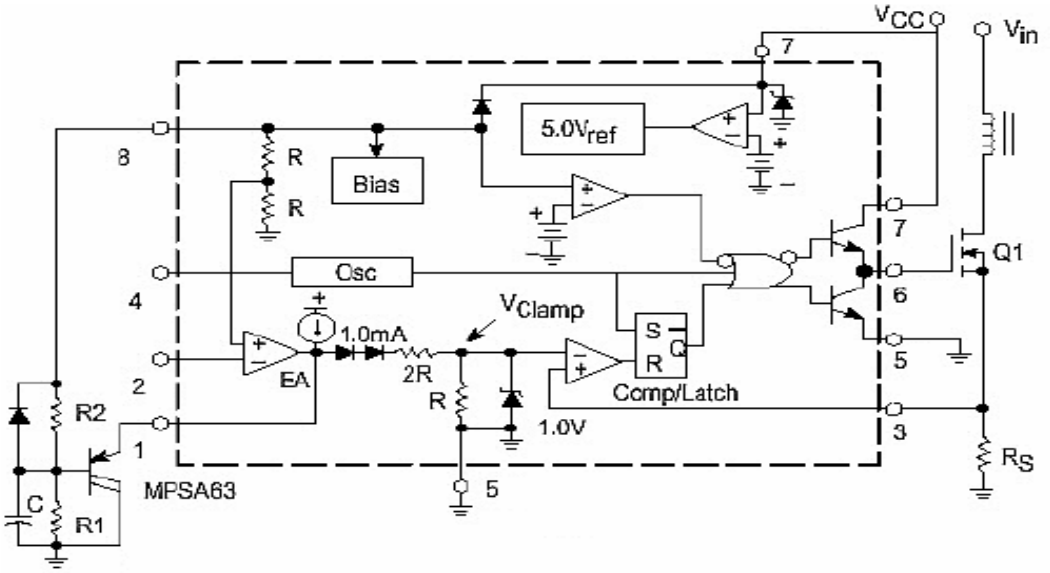
**Fig 5.External Duty Cycle Clamp and Multi Unit Synchronization**




$$Vclamp=\frac{1.67}{(\frac{R2}{R1}+1)}+0.33\times10\text{-}3(\frac{R1R2}{R1+R2}) \quad Ipk(max)=\frac{VClamp}{RS}$$

$$\text{Where:}0\leqq V_{clamp}\leqq 1.0V$$

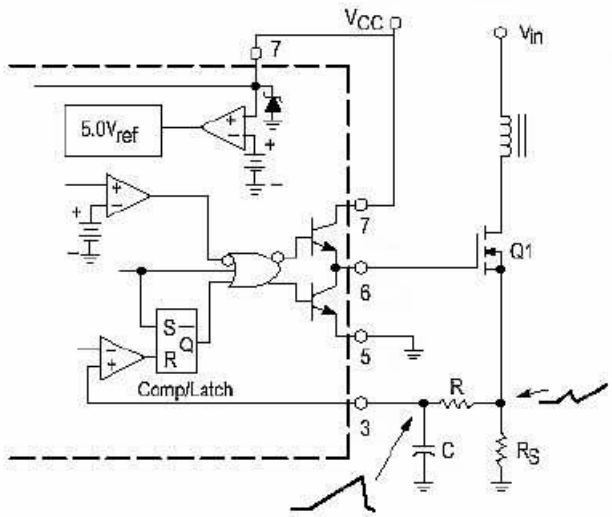
**Fig 6.Adjustable Reduction of Clamp Level**




$$V_{Clamp}=\frac{1.67}{(\frac{R2}{R1}+1)} \quad Ipk(max)=\frac{VClamp}{RS} \quad \text{Where:}0\leqq V_{Clamp}\leqq 1.0V$$

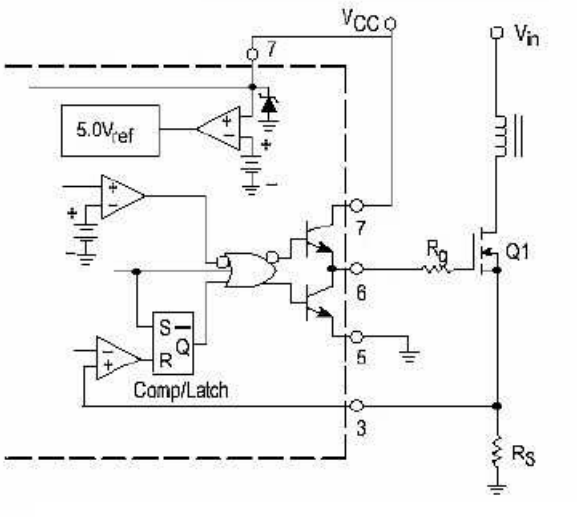
$$t_{softstart}=-\ln\left[1-\frac{Vc}{3V_{Clamp}}\right]C\frac{R1R2}{R1+R2}$$

**Fig 7.Adjustable Buffered Reduction of Clamp Level with Soft-Start**



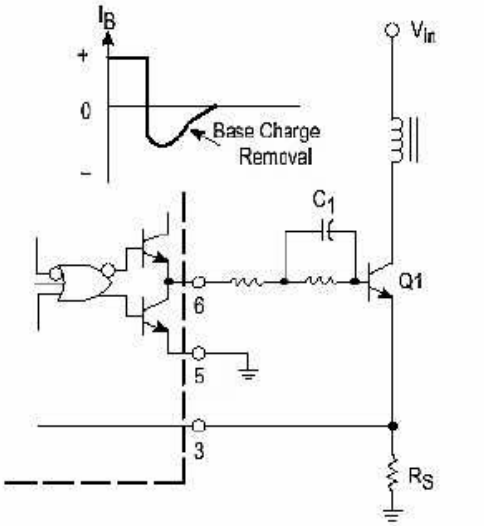

The addition of the RC filter will eliminate instability caused by the leading edge spike on the current waveform.

**Fig 8.Current Waveform Spike Suppression**



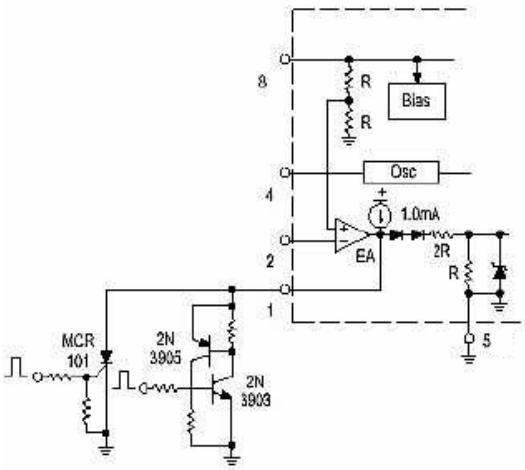

Series gate resistor $R_g$ will damp any high frequency parasitic oscillations caused by the MOSFET input capacitance and any series wiring inductance in the gate-source circuit.

**Fig 9.MOSFET Parasitic Oscillations**




The totem-pole output can furnish negative base current for enhanced transistor turn-off, with the addition of capacitor C1.

**Fig 10.Bipolar Transistor Drive**




The MCR101 SCR must be selected for a holding of less than 0.5mA at $T_{A(min)}$. The simple two transistor circuit can be used in placed of the SCR as shown. All resistor are 10K.

**Fig 11.Latched Shutdown**

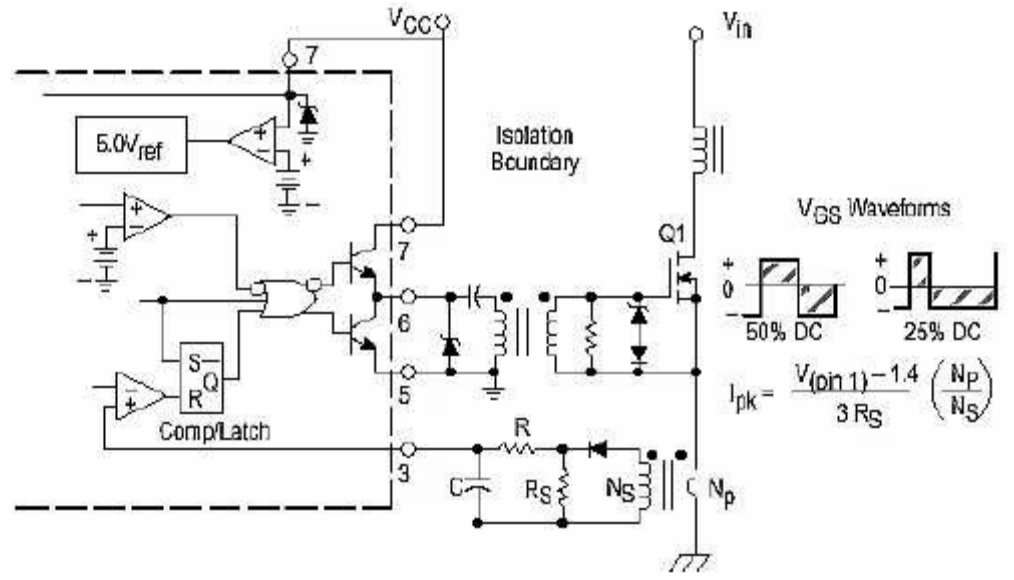
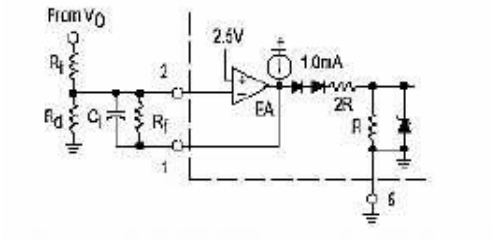
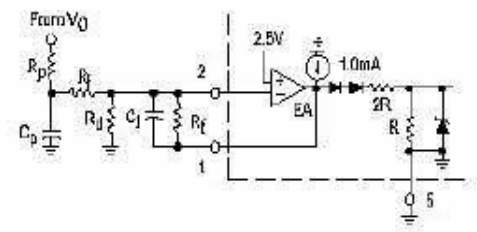



**Fig 12.Isolated MOSFET Drive**




Rf≧8.8K

Error Amp compensation circuit for stabilizing any current-mode topology except for boost and flyback converters operating with continuous inductor current.

Error Amp compensation circuit for stabilizing current-mode topology except for boost and flyback operating with continuous inductor current.

**Fig 13.Error Amplifier Compensation**

## OPERATING DESCRIPTION

The EST3842B/43B/44B/45B series are high performance, fixed frequency, current mode controllers. They are specifically designed for Off-Line and dc-to-dc converter applications offering the designer a cost effective solution with minimal external components. A representative block diagram is shown in Fig

## Oscillator

The oscillator frequency is programmed by the values selected for the timing components RT and CT. Capacitor CT is charged from the 5.0 V reference through resistor RT to approximately 2.8V and discharged to 1.2V by an internal current sink. During the discharge of CT, the oscillator generates and internal blanking pulse that holds the center input of the NOR gate high. This causes the Output to be in a low state , thus producing a controlled amount of output deadtime. Note that many values of RT and CT will give the same oscillator frequency but only one combination will yield a specific output deadtime at a given frequency. The oscillator thresholds are temperature compensated, and the discharge current is

trimmed and guaranteed to within±10% at TJ=25℃. These internal circuit refinemens minimize variations of oscillator frequency and maximum output duty cycle.

In many noise sensitive applications it may be desirable to frequency-lock the converter to an external system clock. This can be accomplished by applying a clock signal to the circuit shown in Fig 3 .For reliable locking, the free-running oscillator frequency should be set about 10% less than the clock frequency. A method for multi unit synchronization is shown in Fig 5. By tailoring the clock waveform, accurate Output duty cycle clamping can be achieved.

## Error Amplifier

A fully compensated Error Amplifier with access to the inverting input and output is provided. It features a typical dc voltage gain of 90dB, and a unity gain bandwidth of 1.0MHz with 57 degrees of phase margin(Fig 19). The noninverting input is internally biased at 2.5V and is not pinned out. The converter output voltage is typically divided down and monitored by the inverting input. The maximum input bias current is –2.0μA which can cause an output voltage error that is equal to the product of the input bias current and the equivalent input divider source resistance.

The Error Amp Output(Pin 1) is provide for external loop compensation(Fig 11). The output voltage is offset by two diode drops (≒1.4V) and divided by three before it connects to the inverting input of the Current Sense Comparator. This guarantees that no drive pulses appear at the Output (Pin 6) when Pin 1 is at its lowest state(VOL). This occurs when the power supply is operating and the load is removed, or at the beginning of a soft-start interval (Fig 4,Fig 7). The Error Amp minimum feedback resistance is limited by the amplifier's source current (0.5mA) and the required output voltgae (VOH) to reach the comparator's 1.0V clamp level:

$$\text{Rf(min)} \fallingdotseq \frac{3.0(1.0V)+1.4V}{0.5mA} = 8800\Omega$$

## Current Sense Comparator and PWM Latch

The EST3842B/43B/44B/45B operate as a current mode controller, whereby output switch conduction is initiated by the oscillator and terminated when the peak inductor current reaches the threshold level established by the Error Amplifier Output/Compensation(Pin 1). Thus the error signal controls the peak inductor current on a cycle-by-cycle basis. The current Sense Comparator PWM Latch configuration used ensures that only a single pulse appears at the Output during any given oscillator cycle.The inductor current is converted to a voltage by inserting the ground referenced sense resistor RS in series with the source of output switch Q1. This voltage is monitored by the Current Sense Input (Pin 3) and compared a level derived from the Error Amp Output . The peak inductor current under normal operating conditions is controlled by the voltage at pin 1 where:

$$\text{Ipk}=\frac{V(pin1)-1.4}{3Rs}$$

Abnormal operating conditions occur when the power supply output is overloaded or if output voltage sensing is lost. Under these conditions, the Current Sense Comparator threshold will be internally clamped to 1.0V. Therefore the maximum peak switch current is:

$$\text{Ipk(max)}=\frac{1.0V}{Rs}$$

When designing a high power switching regulator it becomes desirable to reduce the internal clamp voltage in order to keep the power dissipation of RS to a reasonable level. A simple method to adjust this voltage is shown in Fig 6.The two

external diodes are used to compensate the internal diodes yielding a constant clamp voltage over temperature. Erratic operation due to noise pickup can result if there is an excessive reduction of the Ipk(max) clamp voltage.

A narrow spike on the leading edge of the current waveform can usually be observed and may cause the power supply to exhibit an instability when the output is lightly loaded. This spike is due to the power transformer interwinding capacitance and output rectifier recovery time. The addition of an RC filter on the Current Sense Input with a time constant that approximates the spike duration will usually eliminate the instability;refer to Fig 8.

| Pin | Function | Description |
|---|---|---|
| 1 | Compensation | This pin is Error Amplifier output and is made available for loop Compensation. |
| 2 | Voltage Feedback | This is the inverting input of the Error Amplifier. It is normally connected to the switching power supply output through a resistor divider. |
| 3 | Current Sense | A voltage proportional to inductor current is connected to this input. The PWM uses this information to terminate the output switch conduction. |
| 4 | RT/CT | The Oscillator frequency and maximum Output duty cycle are programmed by connecting resistor RT to Vref and capacitor CT to ground. Operation to 500kHz is possible. |
| 5 | Gnd | This pin is the combined control circuitry and power ground. |
| 6 | Output | This output directly drivers the gate of a power MOSFET. Peak currents up to 1.0A are sourced and sunk by this pin. |
| 7 | VCC | This pin is the positive supply of the control IC. |
| 8 | Vref | This is the reference output. It provides charging current for capacitor CT through resistor RT. |

## Undervoltage Lockout

Two undervoltage lockout comparators have been incorporated to guarantee that the IC is fully functional before the output stage is enabled. The positive power supply terminal (VCC) and the reference output (Vref) are each monitored by separate comparators. Each has built-in hysteresis to prevent erratic output behavior as their respective thresholds are crossed. The VCC comparator upper and lower thresholds are 16V/10V for the EST3842B/44A and 8.4V/7.6V for EST3843B/45B. The Vref comparator upper and lower thresholds are 3.6V/3.4V. The large hysteresis and low startup current of the EST3842B/44B make it ideally suited in off-line converter applications where efficient bootstrap startup techniques are required. The EST3843B/45B are intended for lower voltage dc to dc converter applications. A 36V zener is connected as a shunt regulator from VCC to ground. Its purpose is to protect the IC from excessive voltage that can occur during system startup. The minimum operating voltage for the EST3842B/44B is 11V and 8.2V for the EST3843B/45B.

## Output

These devices contain a single totem pole output stage that was specifically designed for direct drive of power MOSFETs. It's capable of up to ±1.0A peak drive current and has a typical rise and fall time of 50ns with a 1.0nF load. Additional internal circuitry has been added to keep the Output in a sinking mode whenever an eliminates the need for an external pull-down resistor.

## Reference

The 5.0V bandgap reference is trimmed to ±2.0% tolerance at TJ=25℃ on the EST3842B/43B/44B and EST 3845B. It's primary purpose is to supply charging current to the oscillator timing capacitor. The reference has short circuit protection and is capable of providing is excess of 20mA for powering additional control system circuitry.

## DESIGN CONSIDERATIONS

Do not attempt to construct the converter on wire-wrap or plug-in prototype board. High Frequency circuit layout techniques are imperative to prevent pulsewidth jitter. This is usually caused by excessive noise pick-up imposed on the Current Sense or Voltage Feedback inputs. Noise immunity can be improved by lowering circuit impedances at these points. The printed circuit layout should contain a ground plane with low-current signal and high-current switch and output grounds returning on separate paths back to the input filter capacitor. Ceramic bypass capacitors (0.1μF) connected directly to VCC, VC, and Vref may be required depending upon circuit layout. This provides a low impedance path for filtering the high frequency noise. All high current loops should be kept as short as possible using heavy copper runs to minimize radiated EMI. The Error Amp compensation circuitry and the converter output voltage divider should be located close to the IC and as far as possible from the power switch and other noise generating components.

Current mode converters can exhibit subharmonic oscillations when operating at a duty cycle greater than 50% with continuous inductor current. This instability is independent of the regulators closed-loop characteristics and is caused by the simultaneous operating conditions of fixed frequency and peak current detecting. Fig (14A) shows the phenomenon graphically. At t0, switch conduction begins, causing the inductor current to rise at a slope of m1. This slope is a function of the input voltage divided by the inductance. At t1, the Current Sense Input reaches the threshold established by the control voltage. This causes the switch to turn off and the current to decay at a slope of m2 until the next oscillator cycle. The unstable condition can be shown if a perturbation is added to the control voltage, resulting is a small ΔI(dashed line). With a fixed oscillator period, the current decay time is reduced, and the minimum current at switch turn-on (t2) is increased by ΔI+ΔI m2/m1. The minimum current at the next cycle (t3) decreases to (ΔI+ΔIm2/m1)(m2/m1). This perturbation is multiplied by m2*m1 on each succeeding cycle, alternately increasing and decreasing the inductor current at switch turn-on. Several oscillator cycles may be required before the inductor current reaches zero causing the process to commence again.If m2/m1 is greater than 1, the converter will be unstable. Fig(14B) shows that by adding an artificial ramp

that is synchronized with the PWM clock to the control voltage, the ΔI perturbation will decrease to zero on succeeding cycles. This compensation ramp(m3) must have a slope equal to or slightly greater than m2/2 for stability. With m2/2 slope compensation, the average inductor current follows the control voltage yielding true current mode operation. The compensating ramp can be derived from the oscillator and add to either the Voltage Feedback or Current Sense inputs .

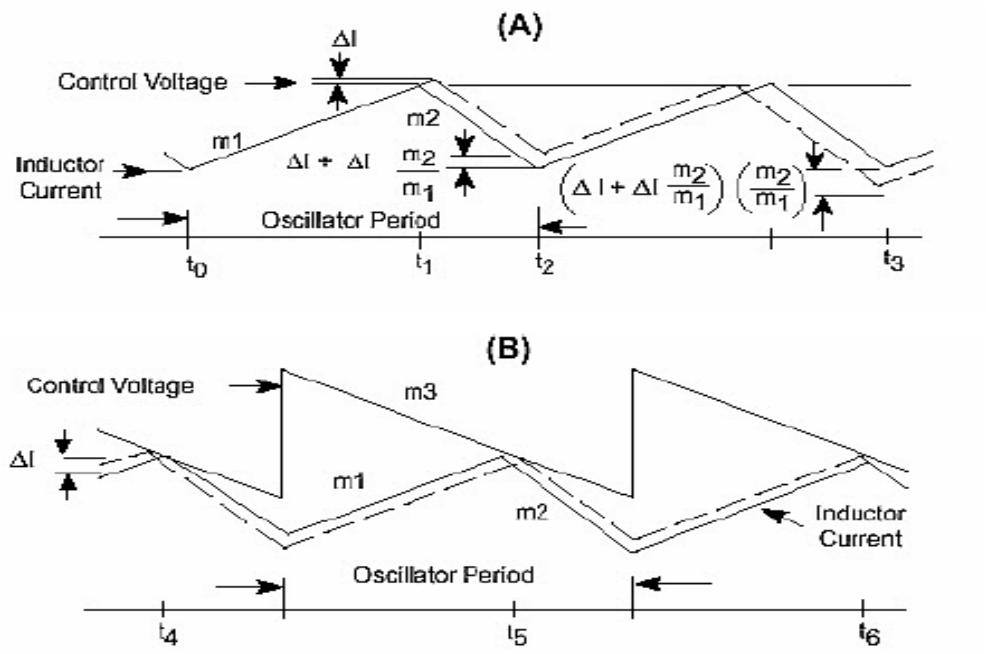



Fig .14

## ELECTRICAL CHARACTERISTICS CURVES

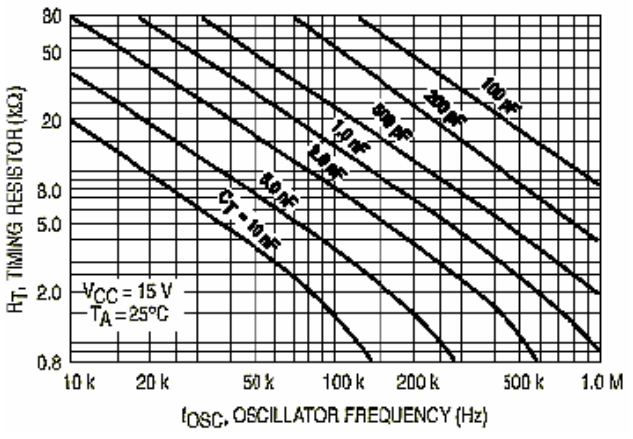



Fig 15.Timing resistor versus oscillator frequency

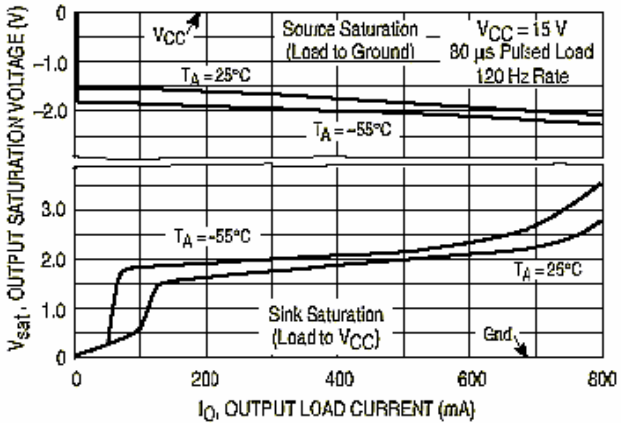



Fig 16.Output saturation voltage versus load current

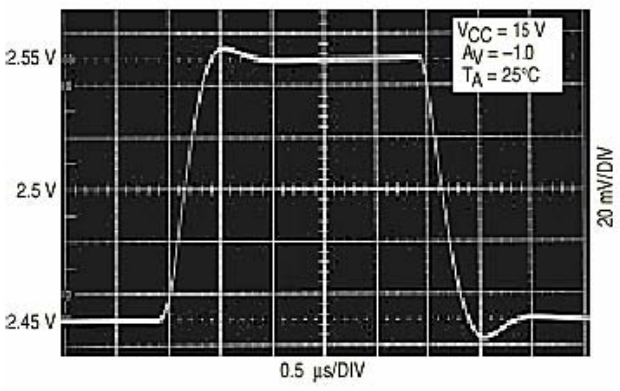



Fig 17.Error amp small signal transient response

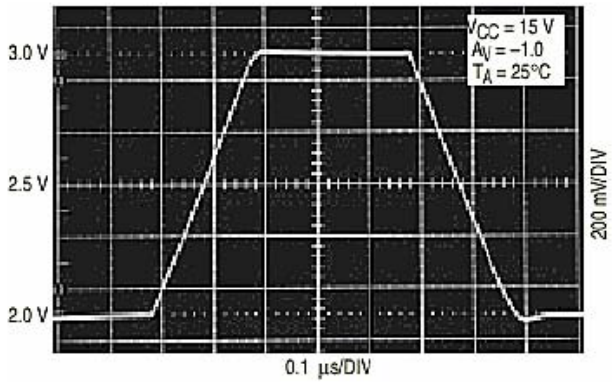



Fig 18.Error amp large signal transient response

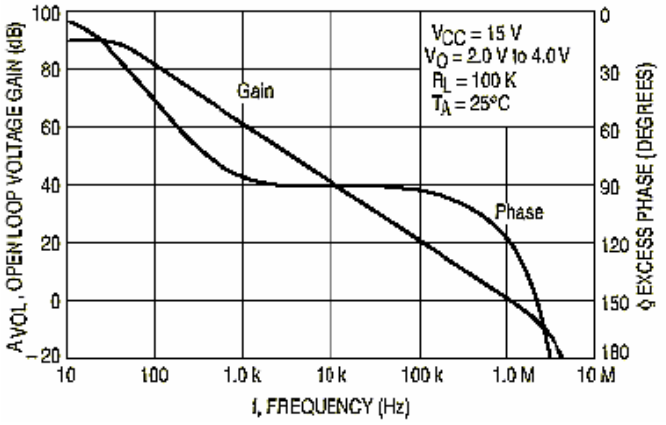



Fig 19.Error amp open-loop gainand phase versus frequency

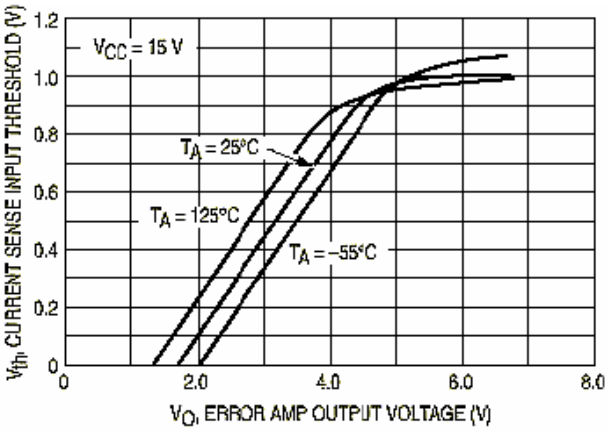



Fig 20.Current sense input thresholdversus error amp output voltage

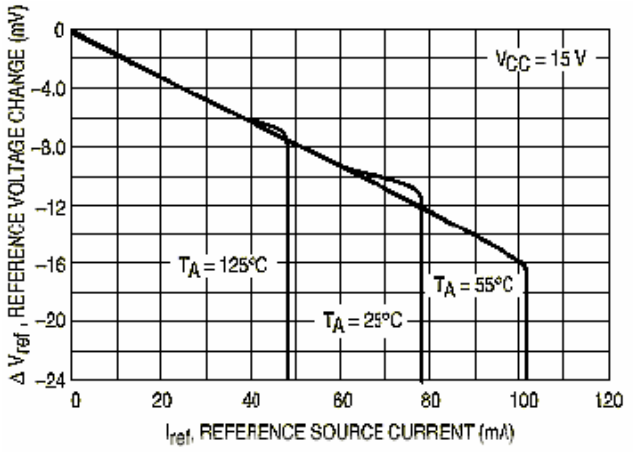



Fig 21.Refrence voltage change versus source current

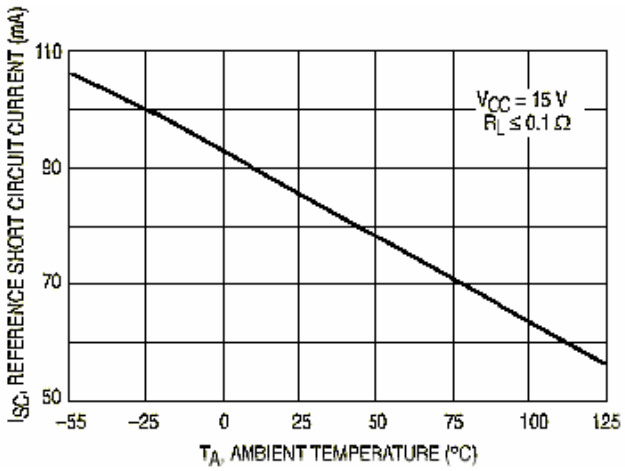



Fig 22.Reference short circuit current versus temperature

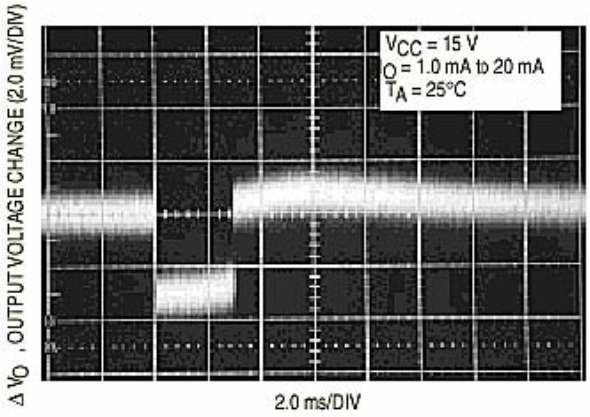



Fig 23.Reference load regulation

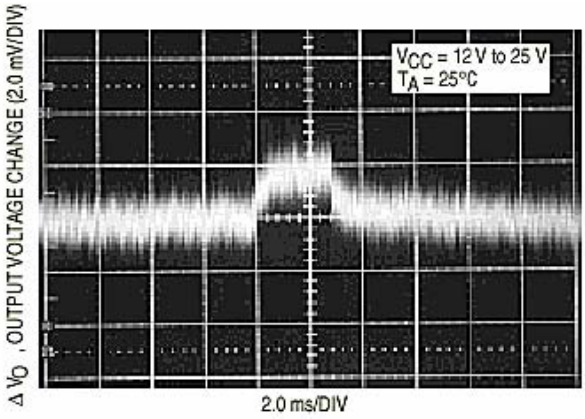



Fig 24.Reference line regulation

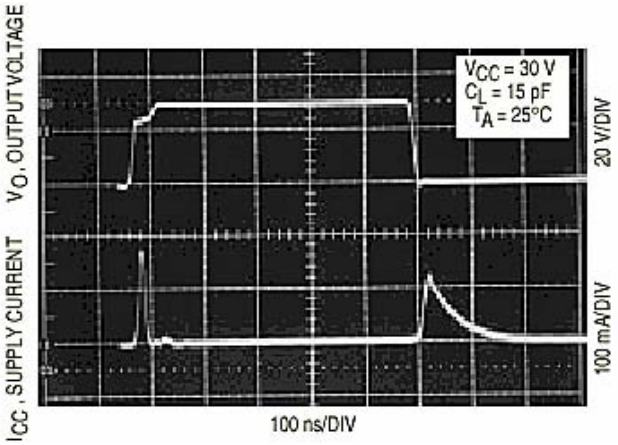



Fig 25.Output cross conduction

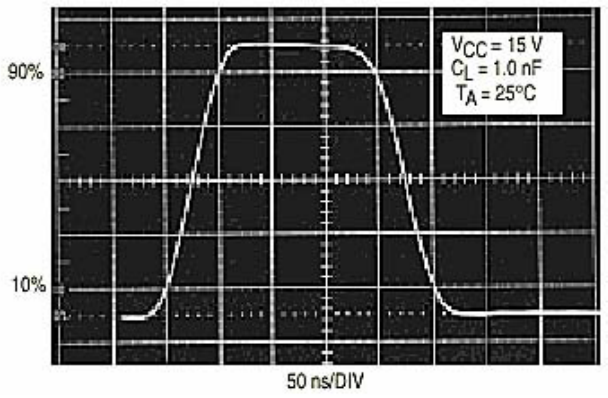
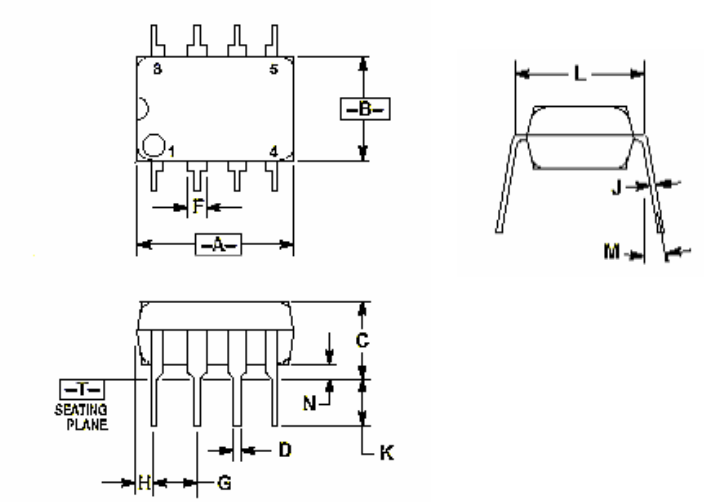



Fig 26.Output waveform

## EXTERNAL DIMENSIONS

| DIM | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 9.40 | 10.16 | 0.370 | 0.400 |
| B | 6.10 | 6.60 | 0.240 | 0.260 |
| C | 3.94 | 4.45 | 0.155 | 0.175 |
| D | 0.38 | 0.51 | 0.015 | 0.020 |
| F | 1.02 | 1.78 | 0.040 | 0.070 |
| G | 2.54 BSC | | 0.100 BSC | |
| H | 0.76 | 1.27 | 0.030 | 0.050 |
| J | 0.20 | 0.30 | 0.008 | 0.012 |
| K | 2.92 | 3.43 | 0.115 | 0.135 |
| L | 7.62 BSC | | 0.300 BSC | |
| M | -- | 10° | -- | 10° |
| N | 0.76 | 1.01 | 0.030 | 0.040 |

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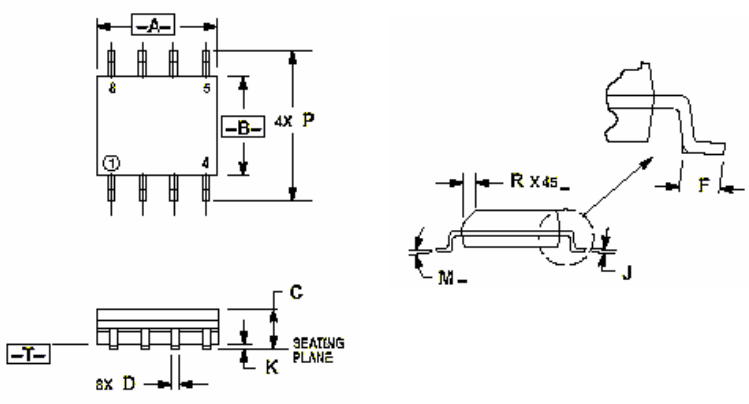
| DIM | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 5.00 | 5.20 | 0.196 | 0.205 |
| B | 3.80 | 4.00 | 0.150 | 0.157 |
| C | 1.35 | 1.75 | 0.054 | 0.068 |
| D | 0.35 | 0.49 | 0.014 | 0.019 |
| F | 0.40 | 1.25 | 0.016 | 0.049 |
| G | 1.27 BSC | | 0.050 BSC | |
| J | 0.18 | 0.25 | 0.007 | 0.009 |
| K | 0.10 | 0.25 | 0.004 | 0.009 |
| M | 0° | 7° | 0° | 7° |
| P | 5.80 | 6.20 | 0.229 | 0.244 |
| R | 0.25 | 0.50 | 0.010 | 0.019 |

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