



## U3525

## LINEAR INTEGRATED CIRCUIT

### REGULATING PWM IC

#### DESCRIPTION

The UTC **U3525** is a pulse width modulator IC and designed for switching power supplies application to improve performance and reduce external parts usage.

A shutdown terminal controls both the soft-start circuitry and the output stages, providing instantaneous turn off through the PWM latch with pulsed shutdown, as well as soft-start recycle with longer shutdown commands. The output stage features NOR logic, giving a LOW output for an OFF state. An under-voltage lockout circuitry, which keeps the outputs off and the soft-start capacitor discharged for sub-normal input voltages, includes approximately 500 mV of hysteresis for jitter free operation. The PWM circuits also feature a latch following the comparator. When a PWM pulses has been terminated, the outputs will remain off for the duration of the period. The latch is reset with each clock pulse. The output stages are totem-pole designs capable of sourcing or sinking in excess of 200mA.

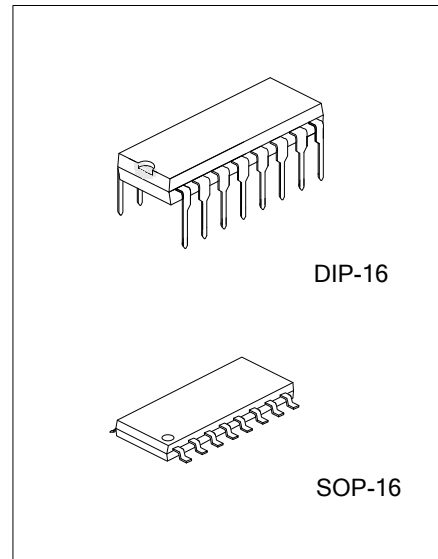
#### FEATURES

- \* Input Voltage: 8~35V
- \* On-chip +5.1V reference is trimmed to  $\pm 1\%$
- \* 100HZ ~ 500KHZ oscillator range
- \* Separate oscillator sync terminal
- \* Adjustable dead time control
- \* Internal soft-start
- \* Pulse-by-pulse shutdown
- \* Input under-voltage lockout with hysteresis
- \* Latching PWM to prevent multiple pulses
- \* Dual source/sink output drivers

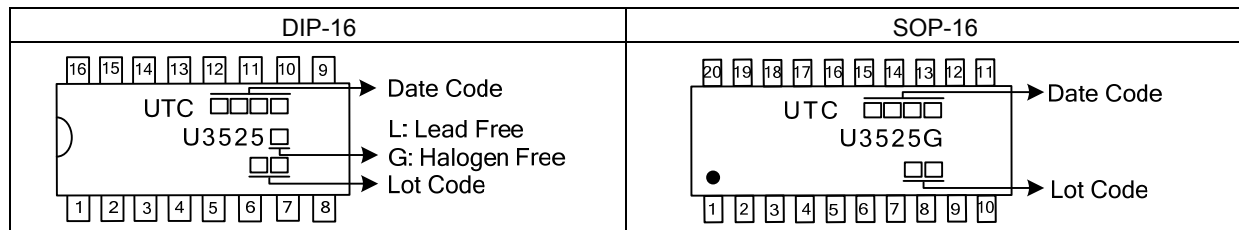
#### ORDERING INFORMATION

| Ordering Number |              | Package | Packing   |
|-----------------|--------------|---------|-----------|
| Lead Free       | Halogen Free |         |           |
| U3525L-D16-T    | U3525G-D16-T | DIP-16  | Tube      |
| -               | U3525G-S16-R | SOP-16  | Tape Reel |

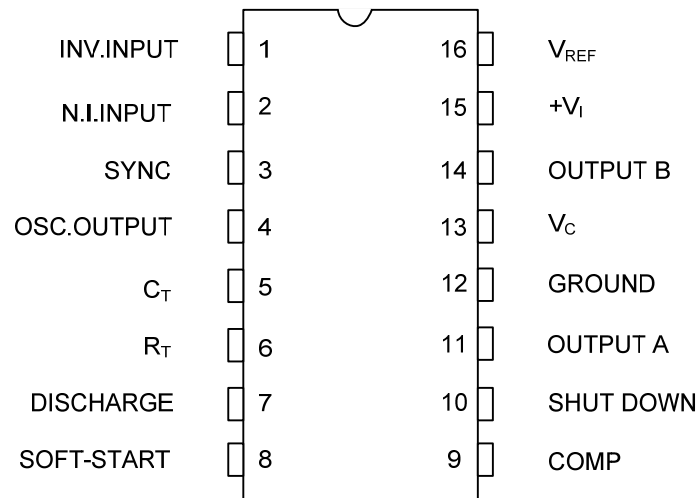
|  |   |
|--|---|
| <p>U3525L-D16-T</p> <p>(1) Packing Type<br/>(2) Package Type<br/>(3) Green Package</p> | <p>(1) R: Tape Reel, T: Tube<br/>(2) D16: DIP-16, S16: SOP-16<br/>(3) L: Lead Free, G: Halogen Free and Lead Free</p> |
|--|---|



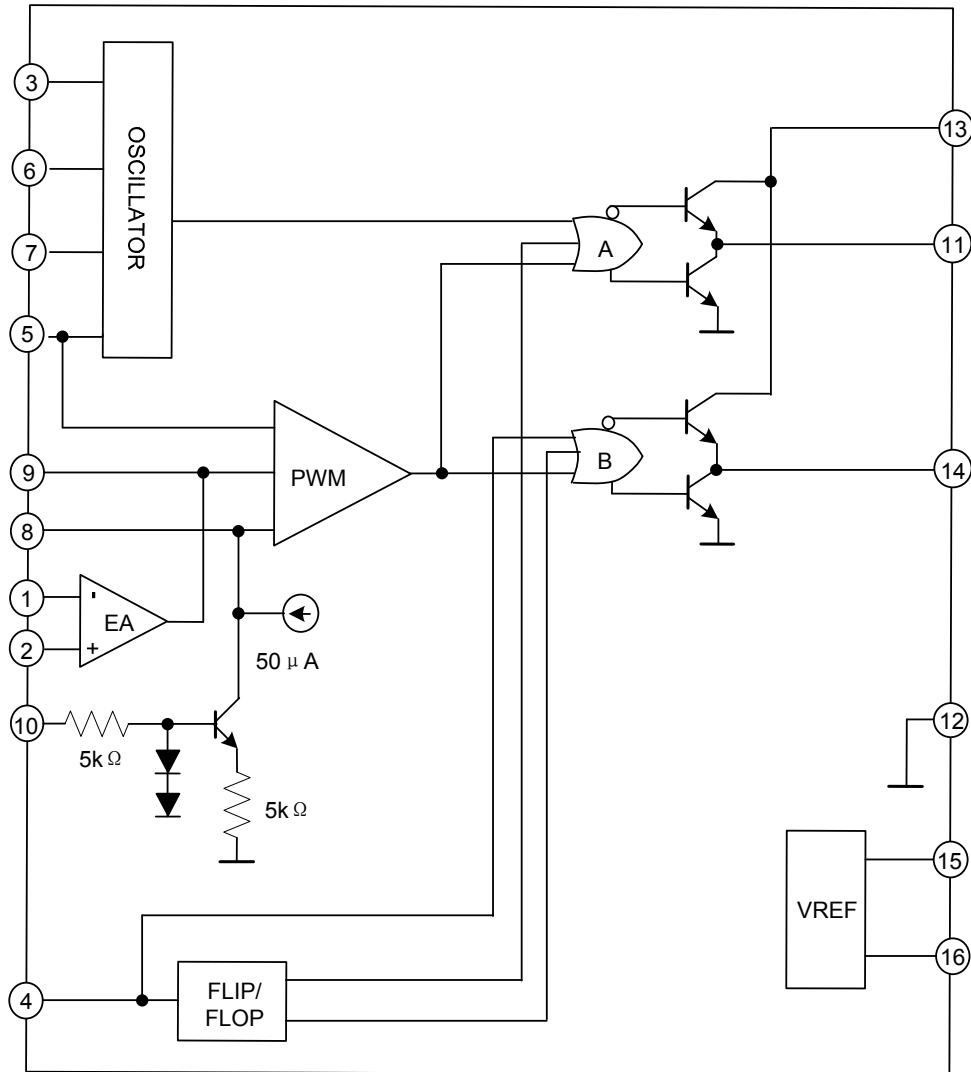
### MARKING



### PIN CONNECTIONS (top view)



### ■ BLOCK DIAGRAM



### ■ ABSOLUTE MAXIMUM RATINGS

| PARAMETER   | SYMBOL    | RATINGS       | UNIT             |
|---|-----------|---------------|------------------|
| Supply Voltage  | $V_{IN}$  | 40            | V                |
| Collector Supply Voltage                                  | $V_C$     | 40            | V                |
| Oscillator Charging Current                               | $I_{OSC}$ | 5             | mA               |
| Output Current, Source or Sink                            | $I_O$     | 500           | mA               |
| Reference Output Current                                  | $I_R$     | 50            | mA               |
| Current through $C_T$ Terminal                            |           | 5             | mA               |
| Logic Inputs  | $I_T$     | - 0.3 ~ + 5.5 | V                |
| Analog Inputs   |           | -0.3 ~ $V_i$  | V                |
| Total Power Dissipation at $T_a=70\text{ }^\circ\text{C}$ | $P_D$     | 1000          | mW               |
| Junction Temperature                                      | $T_J$     | -55 ~ +125    | $^\circ\text{C}$ |
| Operating Ambient Temperature                             | $T_{ORP}$ | 0 ~ +70       | $^\circ\text{C}$ |
| Storage Temperature                                       | $T_{STG}$ | -65 ~ +150    | $^\circ\text{C}$ |

Note: 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.

### ■ RECOMMENDED OPERATING CONDITIONS (NOTE)

| PARAMETER                               | SYMBOL      | RATINGS     | UNIT          |
|---|-------------|-------------|---------------|
| Input Voltage                           | $V_{IN}$    | 8 ~ 35      | V             |
| Collector Supply Voltage                | $V_C$       | 4.5 ~ 35    | V             |
| Sink/Source Load Current (steady state) | $I_{STEAD}$ | 0 ~ 100     | mA            |
| Sink/Source Load Current (peak)         | $I_{PEAK}$  | 0 ~ 400     | mA            |
| Reference Load Current                  | $I_{LOAD}$  | 0 ~ 20      | mA            |
| Oscillator Frequency Range              | $F_O$       | 100 ~ 400K  | Hz            |
| Oscillator Timing Resistor              | $R_O$       | 2 ~ 150     | K $\Omega$    |
| Oscillator Timing Capacitor             | $C_O$       | 0.001 ~ 0.1 | $\mu\text{F}$ |
| Dead Time Resistor Range                | $R_T$       | 0 ~ 500     | $\Omega$      |

Note: Range over which the device is functional and parameter limits are guaranteed.

### ■ THERMAL DATA

| PARAMETER                           |        | SYMBOL        | RATING | UNIT               |
|-------------------------------------|--------|---------------|--------|--------------------|
| Thermal Resistance Junction-ambient | DIP16  | $\theta_{JA}$ | 80     | $^\circ\text{C/W}$ |
|                                     | SOP-16 | $\theta_{JA}$ | 50     | $^\circ\text{C/W}$ |

Note: Thermal resistance junction-alumina with the device soldered on the middle of an alumina supporting substrate measuring 15×20 mm; 0.65 mm thickness with infinite heat sink.

■ ELECTRICAL CHARACTERISTICS ( $V_{IN} = 25V$ , unless otherwise specified)

| PARAMETER  | SYMBOL                    | TEST CONDITIONS   | MIN  | TYP     | MAX     | UNIT          |
|--|---------------------------|---|------|---------|---------|---------------|
| <b>REFERENCE SECTION</b>                                     |                           |   |      |         |         |               |
| Output Voltage   | $V_{REF}$                 | $T_J = 25^\circ C$  | 5    | 5.1     | 5.2     | V             |
| Total Output Variation (Note 1)                              |                           | Line, Load and Temperature                                | 4.95 |         | 5.25    | V             |
| Long Term Stability (Note 1)                                 | $\Delta V_{REF}$          | $T_J = 125^\circ C$ , 1000 hrs                            |      | 20      | 50      | mV            |
| Line Regulation  | $\Delta V_{REF}$          | $V_{IN} = 8 \sim 35 V$                                    |      | 10      | 20      | mV            |
| Load Regulation  | $\Delta V_{REF}$          | $I_L = 0 \sim 20 mA$                                      |      | 20      | 50      | mV            |
| Temp. Stability (Note 1)                                     | $\Delta V_{REF}/\Delta T$ | Over Operating Range                                      |      | 20      | 50      | mV            |
| Output Noise Voltage (Note 1)                                |                           | $10 Hz \leq f \leq 10 kHz$ , $T_J = 25^\circ C$           |      | 40      | 200     | $\mu V_{rms}$ |
| Short Circuit Current  |                           | $V_{REF} = 0$ , $T_J = 25^\circ C$                        |      | 80      | 100     | mA            |
| <b>OSCILLATOR SECTION</b>                                    |                           |   |      |         |         |               |
| Clock Amplitude (Note 1, 2)                                  |                           |   | 3    | 3.5     |         | V             |
| Sync Threshold   |                           |   | 1.2  | 2       | 2.8     | V             |
| Sync Input Current   |                           | Sync Voltage = 3.5 V                                      |      | 1       | 2.5     | mA            |
| Current Mirror   |                           | $I_{RT} = 2 mA$   | 1.7  | 2       | 2.2     | mA            |
| Maximum Frequency  | $f_{MAX}$                 | $R_T = 2 K\Omega$ , $C_T = 470 pF$                        | 400  |         |         | KHz           |
| Minimum Frequency  | $f_{MIN}$                 | $R_T = 200K\Omega$ , $C_T = 0.1\mu F$                     |      |         | 120     | Hz            |
| Clock Width (Note 1, 2)                                      |                           | $T_J = 25^\circ C$  | 0.3  | 0.5     | 1       | $\mu s$       |
| Initial Accuracy (Note 1, 2)                                 |                           | $T_J = 25^\circ C$  |      | $\pm 2$ | $\pm 6$ | %             |
| Voltage Stability (Note 1, 2)                                |                           | $V_{IN} = 8 \sim 35 V$                                    |      | $\pm 1$ | $\pm 2$ | %             |
| Temperature Stability (Note 1)                               | $\Delta f/\Delta T$       | Over Operating Range                                      |      | $\pm 3$ | $\pm 6$ | %             |
| <b>ERROR AMPLIFIER SECTION (<math>V_{CM} = 5.1 V</math>)</b> |                           |   |      |         |         |               |
| Output Low Level   |                           |   |      | 0.2     | 0.5     | V             |
| Output High Level  |                           |   | 3.8  | 5.6     |         | V             |
| Input Offset Voltage   | $V_{OS}$                  |   |      | 2       | 10      | mV            |
| Input Bias Current   | $I_b$                     |   |      | 1       | 10      | $\mu A$       |
| Input Offset Current   | $I_{os}$                  |   |      |         | 1       | $\mu A$       |
| Comm. Mode Reject.   | CMR                       | $V_{CM} = 1.5 \sim 5.2 V$                                 | 60   | 75      |         | dB            |
| Supply Voltage Rejection                                     | PSR                       | $V_{IN} = 8 \sim 35 V$                                    | 50   | 60      |         | dB            |
| DC Open Loop Gain  |                           | $R_L \geq 10 M\Omega$                                     | 60   | 75      |         | dB            |
| DC Transconduct. (Note 1, 3)                                 |                           | $30 K\Omega \leq R_L \leq 1 M\Omega$ , $T_J = 25^\circ C$ | 1.1  | 1.5     |         | ms            |
| Gain Bandwidth Product (Note 1)                              |                           | $G_v = 0 dB$ , $T_J = 25^\circ C$                         | 1    | 2       |         | MHz           |
| <b>PWM COMPARATOR</b>  |                           |   |      |         |         |               |
| Input Threshold (Note 2)                                     |                           | Zero Duty-cycle   | 0.7  | 0.9     |         | V             |
|  |                           | Maximum Duty-cycle  |      | 3.3     | 3.6     | V             |
| Input Bias Current (Note 1)                                  |                           |   |      | 0.05    | 1       | $\mu A$       |
| Minimum Duty-cycle   |                           |   |      |         | 0       | %             |
| Maximum Duty-cycle (Note 2)                                  |                           |   | 45   | 49      |         | %             |
| <b>SHUTDOWN SECTION</b>                                      |                           |   |      |         |         |               |
| Soft Start Low Level   |                           | $V_{SD} = 2.5 V$  |      | 0.4     | 0.7     | V             |
| Shutdown Threshold   |                           | To outputs, $V_{SS} = 5.1 V$ , $T_J = 25^\circ C$         | 0.6  | 0.8     | 1       | V             |
| Shutdown Input Current                                       |                           | $V_{SD} = 2.5 V$  |      | 0.4     | 1       | mA            |
| Soft Start Current   |                           | $V_{SD} = 0 V$ , $V_{SS} = 0 V$                           | 25   | 50      | 80      | $\mu A$       |
| Shutdown Delay (Note 1)                                      |                           | $V_{SD} = 2.5 V$ , $T_J = 25^\circ C$                     |      | 0.2     | 0.5     | $\mu s$       |

### ■ ELECTRICAL CHARACTERISTICS (Cont.)

| PARAMETER  | SYMBOL         | TEST CONDITIONS                              | MIN | TYP | MAX | UNIT |
|--|----------------|--|-----|-----|-----|------|
| <b>OUTPUT DRIVERS (each output) (V<sub>C</sub> = 20 V)</b> |                |  |     |     |     |      |
| Output Low Level   |                | I <sub>SINK</sub> = 20 mA                    |     | 0.2 | 0.4 | V    |
|  |                | I <sub>SINK</sub> = 100 mA                   |     | 1   | 2   | V    |
| Output High Level  |                | I <sub>SOURCE</sub> = 20 mA                  | 18  | 19  |     | V    |
|  |                | I <sub>SOURCE</sub> = 100 mA                 | 17  | 18  |     | V    |
| Under-Voltage Lockout                                      |                | V <sub>COMP</sub> and V <sub>SS</sub> = High | 6   | 7   | 8   | V    |
| Collector Leakage  | I <sub>C</sub> | V <sub>C</sub> = 35 V                        |     |     | 200 | μA   |
| Rise Time (Note 1)   | t <sub>R</sub> | C <sub>L</sub> = 1 nF, T <sub>J</sub> = 25°C |     | 100 | 600 | ns   |
| Fall Time (Note 1)   | t <sub>F</sub> | C <sub>L</sub> = 1 nF, T <sub>J</sub> = 25°C |     | 50  | 300 | ns   |
| <b>TOTAL STANDBY CURRENT</b>                               |                |  |     |     |     |      |
| Supply Current   | I <sub>S</sub> | V <sub>IN</sub> = 35 V                       |     | 14  | 20  | mA   |

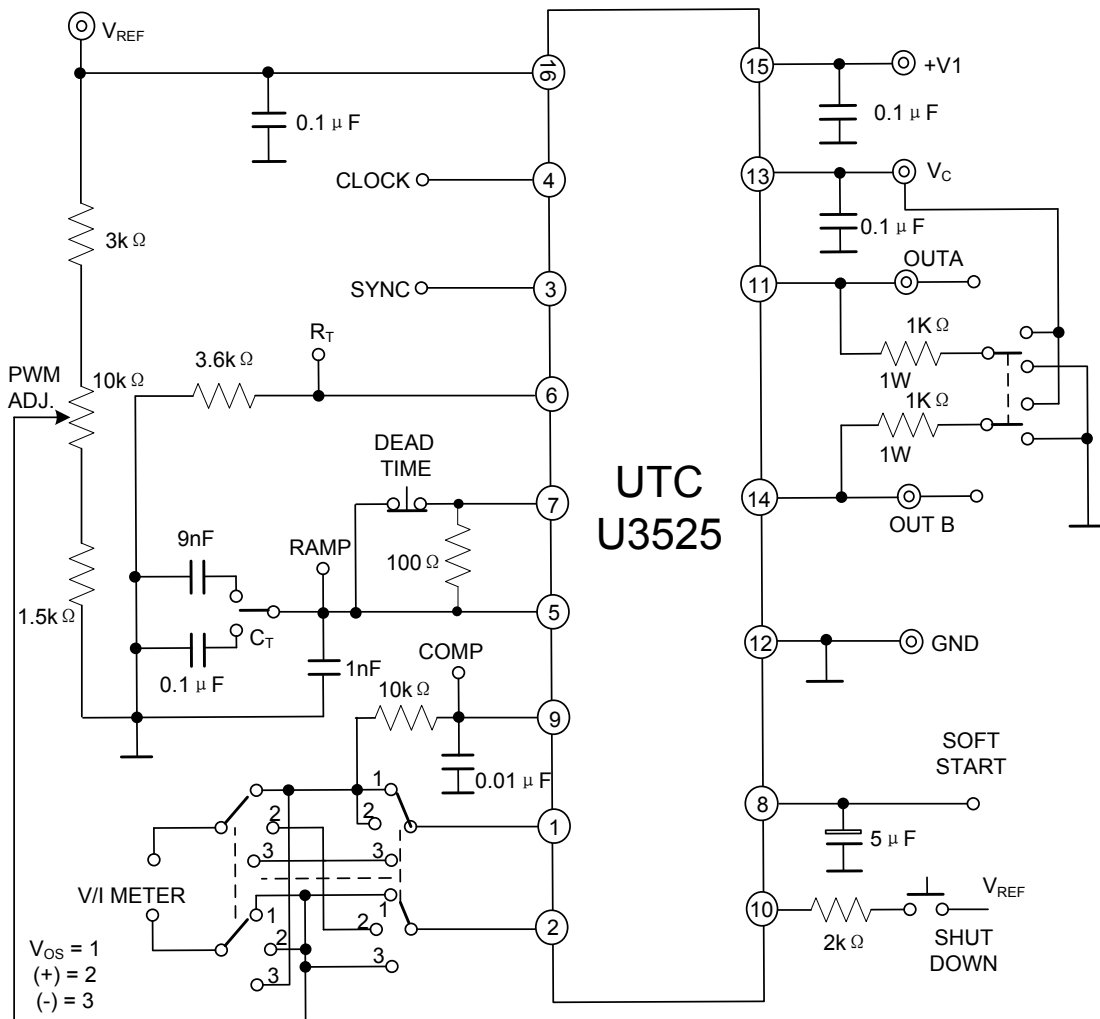
Notes: 1. The parameters are not 100% tested in production.

2. Tested at f<sub>osc</sub>=40 KHz (R<sub>T</sub>=3.6 KΩ, C<sub>T</sub>=10nF, R<sub>D</sub>=0 Ω). Approximate oscillator frequency is defined by :

$$f = \frac{1}{C_T(0.7R_T + 3R_D)}$$

3. DC transconductance (g<sub>M</sub>) relates to DC open-loop voltage gain (G<sub>V</sub>) according to the following equation:  
G<sub>V</sub>=g<sub>M</sub>R<sub>L</sub> where R<sub>L</sub> is the resistance from pin 9 to ground. The minimum g<sub>M</sub> specification is used to calculate minimum G<sub>V</sub> when the error amplifier output is loaded.

## TEST CIRCUIT



## ■ APPLICATION INFORMATION AND CIRCUIT

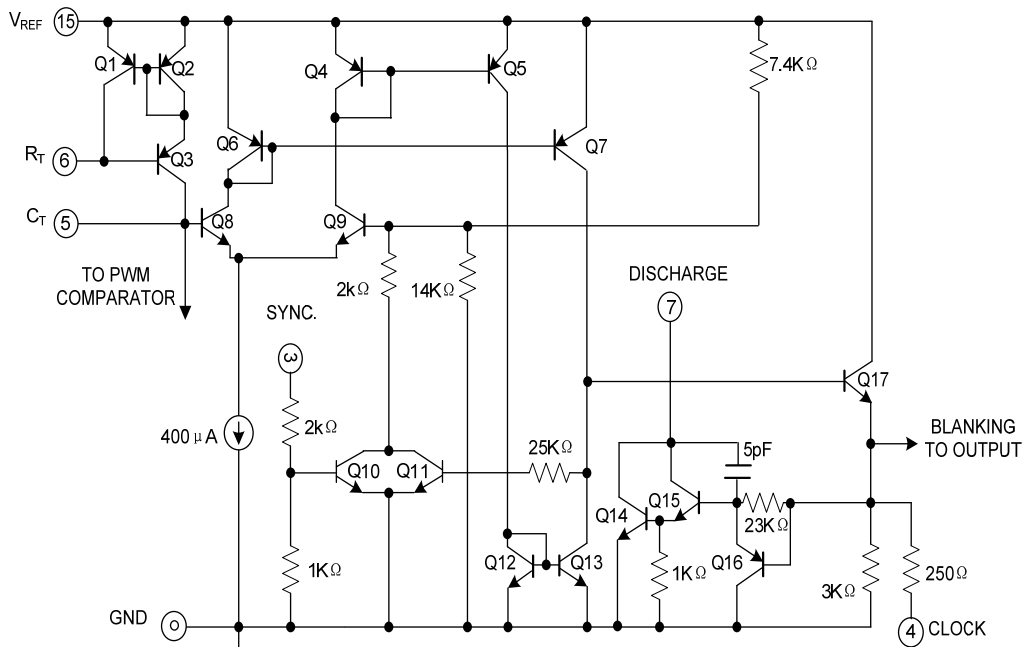
### SHUTDOWN OPTIONS (see Block Diagram)

Since both the compensation and soft-start terminals (Pins 9 and 8) have current source pull-ups, either can readily accept a pull-down signal which only has to sink a maximum of 100µA to turn off the outputs. This is subject to the added requirement of discharging whatever external capacitance may be attached to these pins.

An alternate approach is the use of the shutdown circuitry of Pin 10 which has been improved to enhance the available shutdown options. Activating this circuit by applying a positive signal on Pin 10 performs two functions: the PWM latch is immediately set providing the fastest turn-off signal to the outputs; and a 150µA current sink begins to discharge the external soft-start capacitor. If the shutdown command is short, the PWM signal is terminated without significant discharge of the soft-start capacitor, thus, allowing, for example, a convenient implementation of pulse-by-pulse current limiting. Holding Pin 10 high for a longer duration, however, will ultimately discharge this external capacitor, recycling slow turn-on upon release.

Pin 10 should not be left floating as noise pickup could conceivably interrupt normal operation.

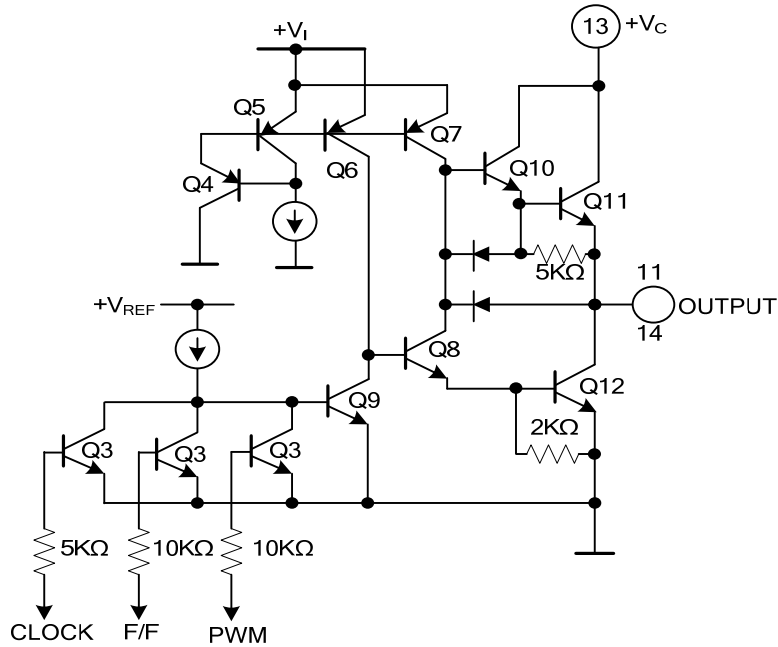
### OSCILLATOR SCHEMATIC



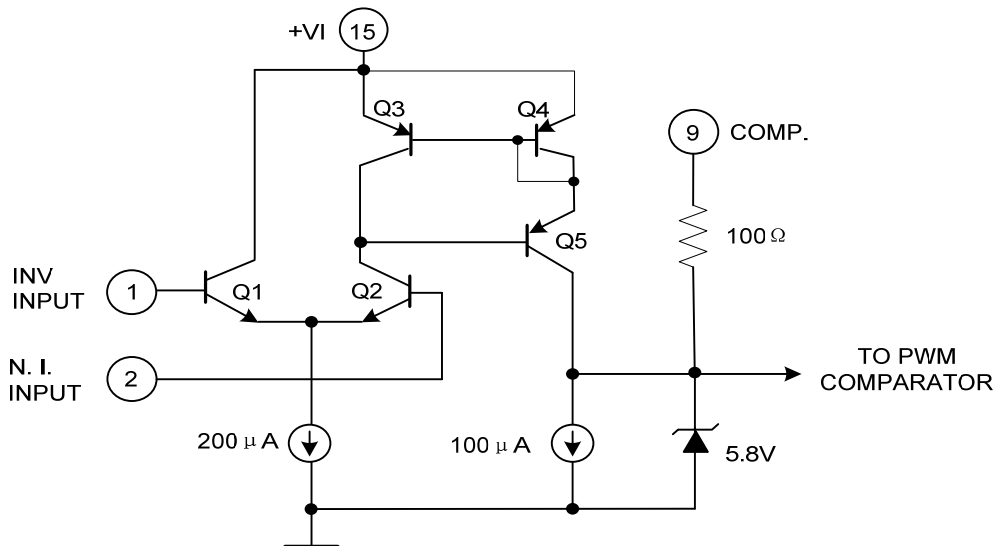


## APPLICATION INFORMATION AND CIRCUIT(Cont.)

### OUTPUT CIRCUIT (1/2 CIRCUIT SHOWN)

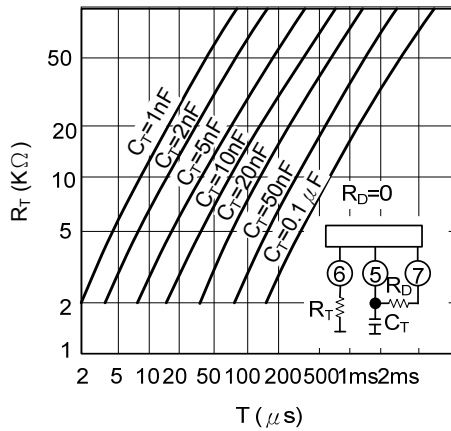


### ERROR AMPLIFIER

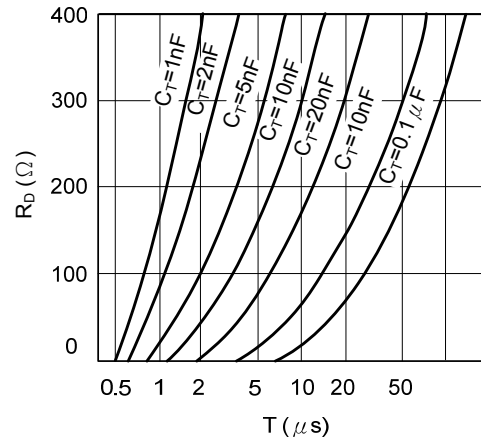


## ■ TYPICAL CHARACTERISTICS

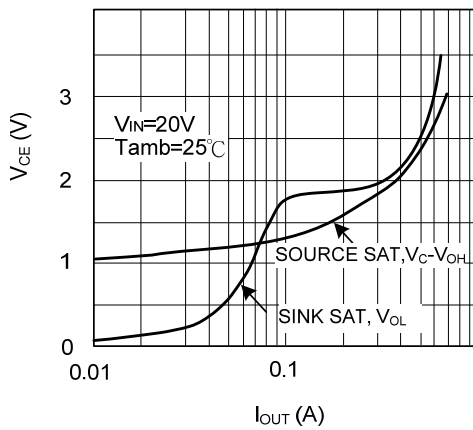
Oscillator Charge Time vs.  $R_T$  and  $C_T$



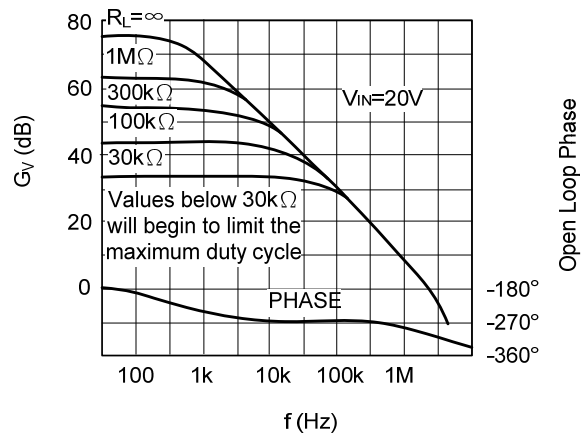
Oscillator DisCharge Time vs.  $R_D$  and  $C_T$



Output Saturation Characteristics



Error Amplifier Voltage Gain and Phase vs. Frequency



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