BICMOS PWM CONTROLLERS

FEATURES

- **Low Power BICMOS Construction**
- **Low Supply Current at 20 kHz ..... 1.0mA Typ**
- **Latch-Up Immunity ..... >500mA on Outputs**
- **Below Rail Input Protection ..... – 5V**
- **High Output Drive ..... 500mA Peak**
- **Fast Rise/Fall Time ..... 50nsec @ 1000pF**
- **High Frequency Operation ..... Up to 1MHz**
- **Tri-state Sync Pin for Easy Parallel Operation**
- **Under Voltage Hysteresis Guaranteed**
- **Shutdown Pin Available**
- **Double-Ended**
- **Soft Start, With Small Cap**
- **Low Prop Delay Shutdown to Output ..... 140nsec Typ.**

GENERAL DESCRIPTION

The TC35C25 family of PWM controllers are CMOS implementations of the industry standard 3525 voltage mode SMPS ICs.

These second generation CMOS devices employ TelCom Semiconductors' Tough BiCMOS™ process for latch-up proof operation. They offer much lower power consumption than any of their previous CMOS or bipolar counterparts.

These controllers have separate supply pins for the control and output sections of the circuit. This allows "boot-strap" operation. The CMOS output stage allows the output voltage to swing to within 25mV of either rail.

Other improved features include tighter hysteresis and undervoltage start-up specifications over temperature, and very low input bias current on all inputs.

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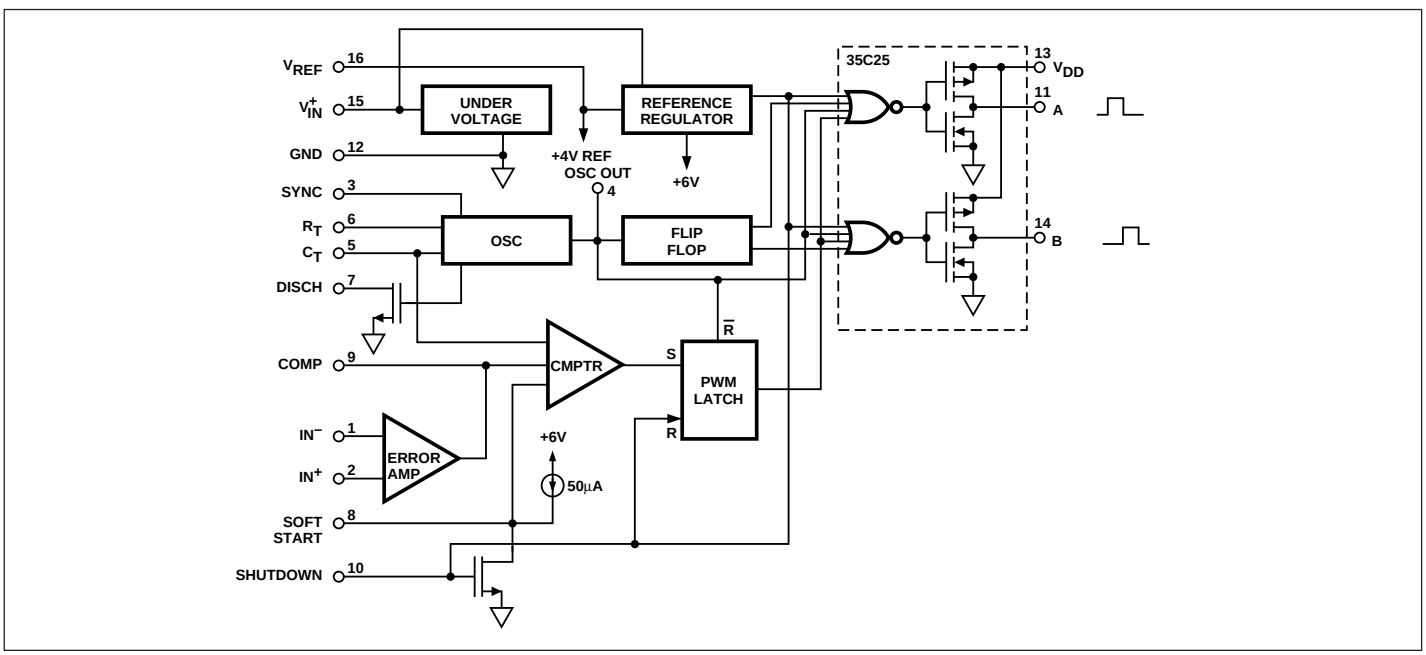
ORDERING INFORMATION

Part No.	Configuration	Pkg./Temperature
TC25C25EOE	Non-Inverting	16-Pin SOIC (Wide) – 40°C to +85°C
TC25C25EPE	Non-Inverting	16-Pin Plastic DIP (Narrow) – 40°C to +85°C
TC35C25COE	Non-Inverting	16-Pin SOIC (Wide) 0°C to +70°C
TC35C25CPE	Non-Inverting	16-Pin Plastic DIP (Narrow) 0°C to +70°C

FUNCTIONAL BLOCK DIAGRAM



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ABSOLUTE MAXIMUM RATINGS*

Supply Voltage 18V
Maximum Chip Temperature ..... 150°C
Storage Temperature ..... – 65°C to +150°C
Lead Temperature (10 sec) ..... 300°C
Package Thermal Resistance
- PDIP $R_{\theta J-A}$ ..... 125°C/W
- PDIP $R_{\theta J-C}$ ..... 45°C/W
- SOIC $R_{\theta J-A}$ ..... 250°C/W
- SOIC $R_{\theta J-A}$ ..... 75°C/W

Operating Temperature
- 25C2x ..... $– 40°C \le T_A \le +85°C$
- 35C2x ..... $0°C \le T_A \le +70°C$

*Static-sensitive device. Unused devices must be stored in conductive material. Protect devices from static discharge and static fields. Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied.

ELECTRICAL CHARACTERISTICS: Unless otherwise stated, these specifications apply for $– 40°C < T_A < +85°C$ for the TC25C25Exx; and $0°C < T_A < +70°C$ for the TC35C25Cxx; V_{IN} and V_{DD} = 16V; R_T = 3.7kΩ; C_T = 1000pF; RD = 760Ω.

Parameter	Test Conditions	Min	Typ	Max	Units
Reference Section					
Output Voltage	T_J = 25°C, I_O = 1mA	3.9	4	4.1	V
Line Regulation	V_{IN} = 8V to 18V	—	±4	±10	mV
Load Regulation	I_I = 1mA to mA	—	±4	±15	mV
Temp Coefficient	Note 1	—	±0.01	±0.4	mV/°C
V_{REF}	Worst Case	3.85	4	4.15	V
Long Term Drift	T_J = 25°C, (Note 1)	—	±50	—	mV/1000Hrs
Short Circuit	V_{REF} to GND	20	40	70	mA
Output Noise	T_J = 25°C, 10 Hz ≤ f ≥ 10 kHz, (Note 1)	—	21	—	µV(rms)
Oscillator Section					
Initial Accuracy	T_J = 25°C, at 97 kHz	—	±2	±3	%
Voltage Coefficient	V_{IN} = 8V to 18V	—	±0.01	±0.1	%/V
Temp Coefficient	Note 1	—	±0.025	±0.06	%/°C
OSC Ramp Amplitude		2.9	3.2	3.4	V
Reset Switch $R_{DS\ (ON)}$	T_J = 25°C	30	50	60	Ω
Clock Amplitude	f_{osc} = 100kHz, R_L = 1MΩ, (Note 1)	4.9	5.5	6.7	V
Clock Min Width	T_J = 25°C, R_D = 0Ω, (Note 1) C_T = 100pF, R_T = 1Ω	—	170	200	nsec
Sync Threshold	R_T Pin Tied to V_{REF}, C_T Pin at GND	1.8	2.2	2.8	V
Sync Input Current	Sync Voltage = 4V, V(R_T) = 4V	—	—	±1	µA
Min Sync Pulse Width	T_J = 25°C, Sync Amplitude = 5V, (Note 1)	—	130	175	nsec
Max OSC Freq	R_T = 1Ω, C_T = 100pF, R_D = 0Ω, (Note 1)	1.0	—	—	MHz
Error Amplifier Section (V_{CM} = 2.5V)					
Input Offset Voltage		—	±5	±15	mV
Input Bias Current	T_J = 25°C	—	±50	±200	pA
Input Offset Current	T_J = 25°C	—	±25	±100	pA
DC Open Loop Gain	R_L = 100kΩ	70	85	—	dB
Gain Bandwidth Product	Note 1	0.7	0.9	1.2	MHz
Output Low Level	R_L = 100kΩ (N Channel)	—	10	20	mV
Output High Level	R_L = 100kΩ (NPN)	4.9	5.4	5.9	V
CMRR	V_{CM} = 0.5 to 4.7V	60	75	—	dB

ELECTRICAL CHARACTERISTICS: Unless otherwise stated, these specifications apply for – 40°C < T_A < +85°C for the TC25C25Exx; and 0°C <T_A < +70°C for the TC35C25Cxx; V_{IN} and V_{DD} = 16V; R_T = 3.7kΩ; C_T = 1000 pF; RD = 760 Ω.

Parameter	Test Conditions	Min	Typ	Max	Units
Supply Voltage Rejection	V_{IN} = 8V to 18V	90	120	—	dB
Slew Rate	C_{LOAD} = 50pF, ACL = 1 V(EA+) = 1V to 3V Pulse, (Note 1)	— —	1 —	— —	V/µsec
Threshold Hysteresis		0.6	0.8	1	V
Total Standby Current					
Supply Current		—	1.2	2.5	mA
Start-Up Current		—	250	350	µA
PWM Comparator					
Min. Duty Cycle	Note 1, T_J = 25°C	—	—	0	%
Max Duty Cycle	T_J = 25°C, f_{OSC} = 100kHz, (Note 1)	45	49	—	%
Input Threshold	V(C_T) = 0.6V	0.5	0.6	0.7	V
Input Threshold	V(C_T) = 3.6V	3.4	3.6	3.7	V
Input Bias Current	Note 1, T_J = 25°C	—	—	±1	µA
Soft Start Section					
Soft Start Current	$V_{SHUTDOWN}$ = 0V	30	46	75	µA
Soft Start Voltage	$V_{SHUTDOWN}$ = 3V	—	30	100	mV
Shutdown Input Current	$V_{SHUTDOWN}$ = 3V	—	±1	±100	nA
Min Shutdown Pulse Width	$V_{SHUTDOWN}$ = 5V, (Note 1)	—	20	40	nsec
Shutdown Delay	$V_{SHUTDOWN}$ = 5V, (Note 1)	130	140	220	nsec
Shutdown Threshold		1.5	2.4	3	V
Output Drivers (each output)					
Output Low Level RDS (ON)	I_{SINK} = 20mA	—	13	25	Ω
Output High Level RDS (ON)	I_{SOURCE} = 20mA	—	20	35	Ω
Rise Time	C_L = 1_{nF}, (Note 1)	—	55	80	nsec
Fall Time	C_L = 1_{nF}, (Note 1)	—	40	65	nsec
Power Supply					
Supply Current	f_{OSC} = 100kHz	—	2	3	mA
UV Lockout Threshold		6.45	7	7.3	V
UV Lockout Hysteresis		1.7	2.2	2.5	V
Start-up Current		—	75	200	µA

NOTE: 1. Not Tested.

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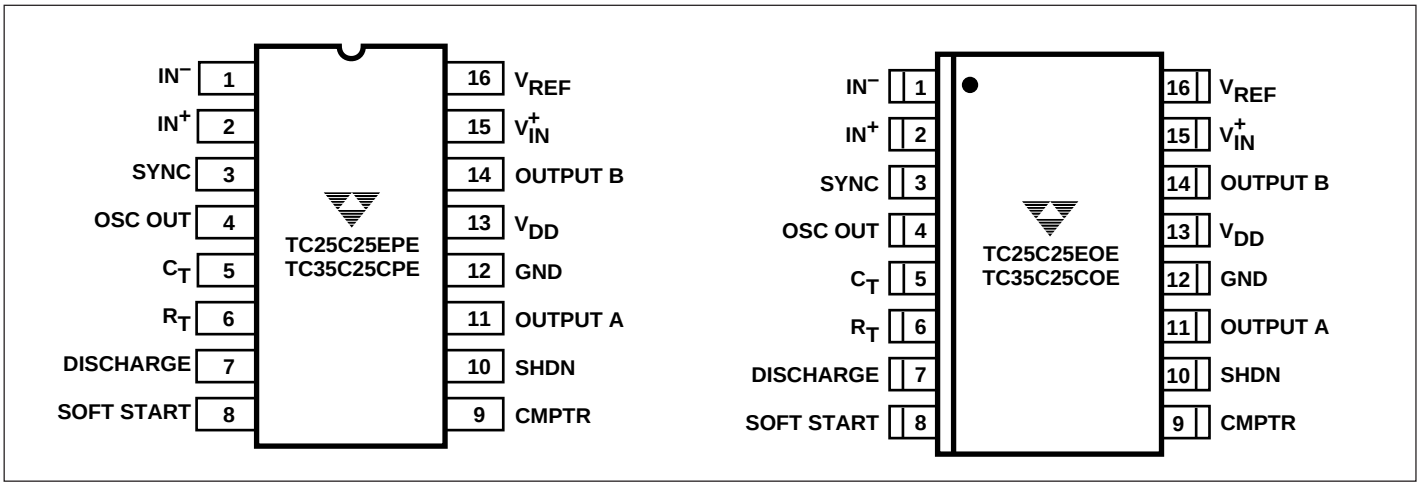
PIN CONFIGURATION (DIP AND SOIC)



PIN DESCRIPTION

Pin No.	Symbol	Description
1	IN^-	Error Amplifier inverting input for output voltage reference input and amplifier gain set.
2	IN^+	Error Amplifier, non-inverting input for output voltage feedback to regulate voltage.
3	SYNC	Input pin for PWM controller oscillator synchronization of two or more controllers from an external clock output or from another PWM controller oscillator output.
4	OSC OUT	Pin for output of the internal oscillator. This signal can be used as a master oscillator to sync other oscillators to run at the same timing period.
5	C_T	Pin is the capacitor timing input to set oscillator frequency in conjunction with pin 6 R_T timing resistor.
6	R_T	Pin for timing resistor input to set oscillator frequency by setting the charge current into capacitor C_T of pin 5.
7	DISCHARGE	Pin for discharging the timing capacitor, C_T of pin 5. During discharging time period, PWM controller output is disabled. This is called dead time. With a resistor between pin 7 and pin 5, the dead time can be controlled.
8	SOFT START	Pin for soft starting the power supply. A capacitor from this pin to GND pin 12 will limit duty cycle till capacitor is charged above error amplifier output.
9	CMPTR	Pin for compensation of the feedback loop response.
10	SHDN	Pin for terminating both outputs of pins 11 and 14. This will shutdown the power supply outputs. A positive input with shutdown threshold of 2.4V is required for shutdown.
11	OUTPUT A	Pin for output drive of phase A to drive push pull transistor A.
12	GND	Pin for ground return for all inputs and output signals.
13	V_{DD}	Pin for power supply input to operate the output drivers A and B.
14	OUTPUT B	Pin for output drive of phase B to drive push pull transistor B.
15	V_{IN}^+	Pin for voltage bias supply input for all PWM controller functions except output drive circuits.
16	V_{REF}	Pin is the reference supply output voltage of 4.0 volts that may be used for any voltage reference purposes such as a reference to control output voltage.

OUTPUT SECTION

The output stage of the TC35C25 is comprised of two pairs of complimentary CMOS drivers operating in a push-pull mode. Each output is capable of sinking or sourcing nearly 500mA of peak current. They are also capable of absorbing just as much "kick-back" current without latching.

SOFT START

A soft restart recovery rate may be selected by placing a capacitor from SOFT START (pin 8) to ground. The calculation for the recovery timing is approximately 60 msec/μF.

SOFT START will mediate the start-up from under voltage recovery, power-on, or SHUTDOWN.

SHUTDOWN

There is a minimum delay, non-latching shutdown feature on the TC35C25 PWM controller. Both outputs may be turned off by applying a positive voltage to SHUTDOWN (pin 10). Typical shutdown threshold is 2.4V. Returning the pin back to ground will reinitialize the soft start cycle.

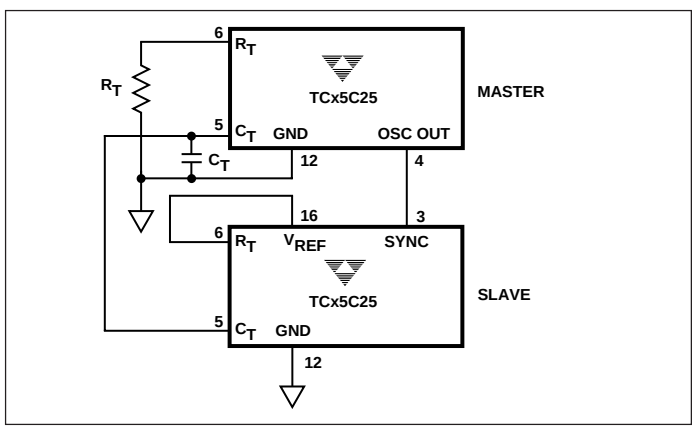
OSCILLATOR SECTION

A tri-state feature has been added to accommodate systems which require multiple controllers to be run in a "master/slave" configuration. The timing resistor pin (R_T, pin 6) may be tied to V_{REF} to place the sync pin (SYNC, pin 3) in a high impedance state. This will allow the chip to be clocked from an external source.

The sync output (OSC OUT, pin 4) of the TC35C25 can drive several sync inputs configured in this manner.

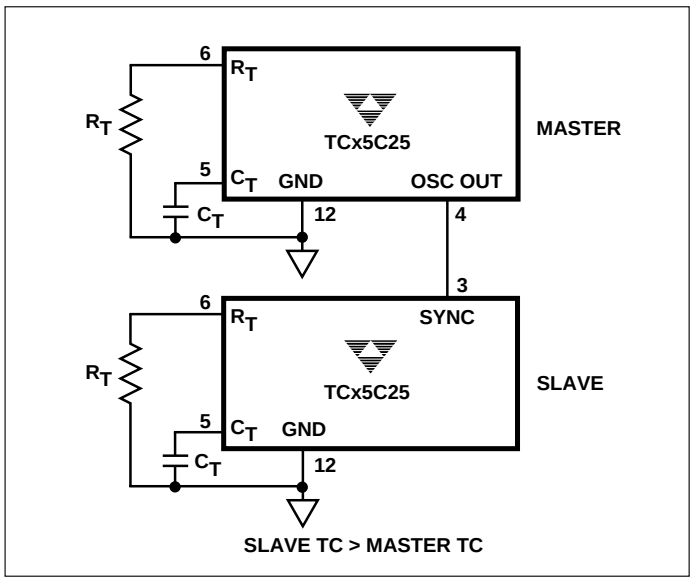
OSCILLATOR SYNCHRONIZATION

Synchronization of two TC35C25's can be done by making one PWM Controller as the master oscillator to synchronize the slave as follows:



OSCILLATOR SYNCHRONIZATION WITH SEPARATE RC TIMER

Synchronization can also be done by having a separate RC timing circuit on the slave oscillator that is slightly lower frequency than the master oscillator. The sync input will not be in a high impedance state so the number of slave oscillators is limited. This method of synchronization is useful when slave oscillator is located in a different location. When a separate RC timer is used in the slave controller, ground loop noise pickup in the oscillator is minimized.



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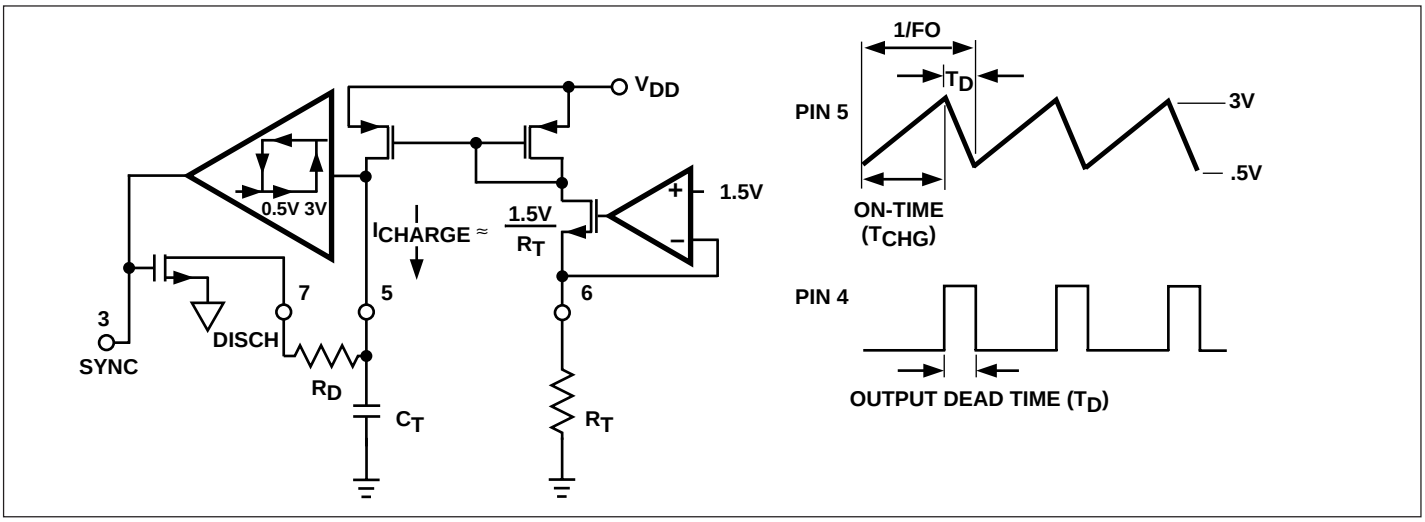
OSCILLATOR FREQUENCY AND OUTPUT DEAD TIME



The oscillator frequency (F_O) = $\frac{1}{T_{CHG} + T_D}$

T_{CHG} is the charging duration of C_T. One of the PWM Controller output drivers is ON during charging of C_T. T_D is the output dead time when both of the output drivers are inactive. Resistor (R_T) sets the Capacitor (C_T) charging current.

To choose an oscillator frequency (F_O), first select the period of dead time (T_D) required. Calculate the capacitor charge time (T_{CHG}).

$$T_{CHG} = \frac{1 - F_O \times T_C}{F_O}$$

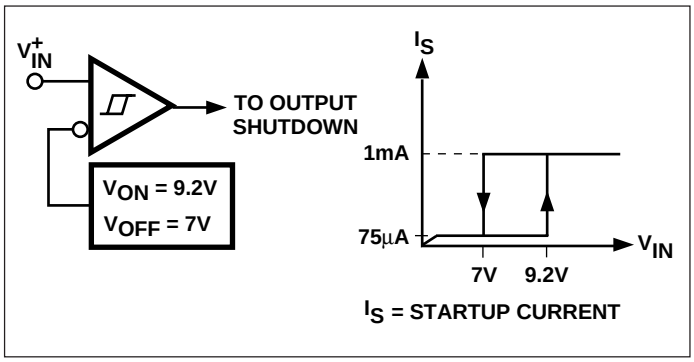
Select a capacitor in the range of 100 pF to 1000 pF for C_T. See graph in Typical Characteristic Curve. Calculate capacitor charging current (I_{CHG}).

$$I_{CHG} = \frac{2.5 \times C_T}{T_{CHG}}$$

C_T in Farads, T_{CHG} in seconds, I_{CHG} in amperes, and R_T in ohms.

$$R_T = \frac{1.5}{I_{CHG}}$$

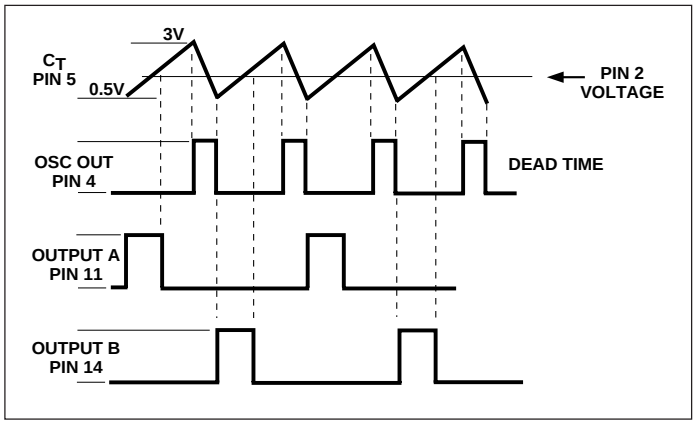
The resistor (R_D) controls the period of dead time (T_D). During dead time this resistor (R_D) current is the sum of the C_T discharge current and the I_{CHG} current. The value for R_D can range from >1Ω to <900Ω. Dead time increases when R_D is increased. See graph in Typical Characteristic Curve for dead time resistor value.

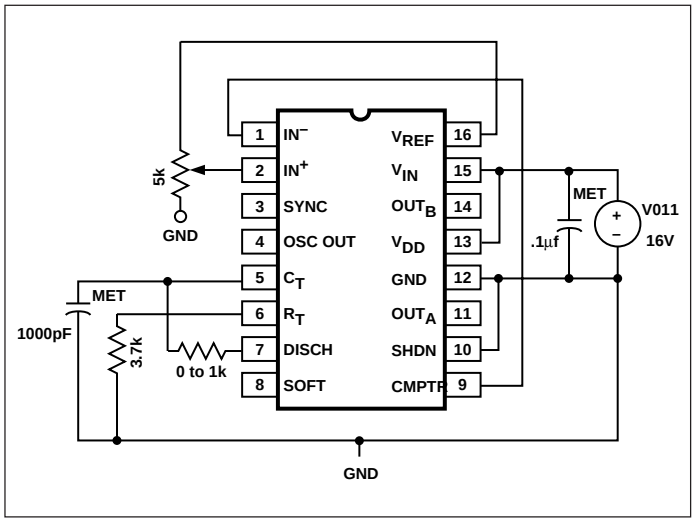


UNDERVOLTAGE LOCKOUT SECTION

The typical turn on threshold is 9.2V for operation of this family of PWM Controllers. When supply voltage at pin 15 drops below 7V, after normal operation above 9.2V, lockout occurs and both output drives to pin 11 and 14 are terminated.

BENCH TEST OPERATIONAL SIMULATION WAVEFORMS





The 5k potentiometer sets a reference voltage at pin 2. When ramp voltage of pin 5 reaches this reference voltage, output drive pulse is active ON. Varying the discharge resistor will vary the dead time. Increasing the discharge resistor will effect an increase in the dead time.

REPLACING BIPOLAR VERSIONS WITH CMOS

Although the pin-out and functions are the same for both the Bipolar and CMOS versions, there are several differences that need to be taken into account. The reference voltage on the TC35C25 is 4V instead of 5V and the oscillator ramp is 3V, not 4V. The R_T and C_T values are different for any particular frequency and dead-time requirement.

The most important difference is that the absolute maximum rating of the V_{DD} and V_{IN} voltages for the TC35C25 is 18V, whereas the UC3525 is 40V.

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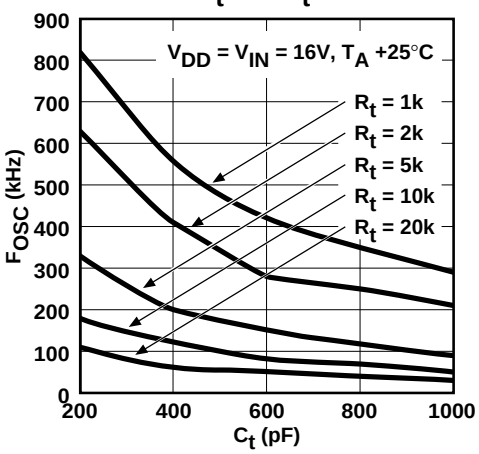
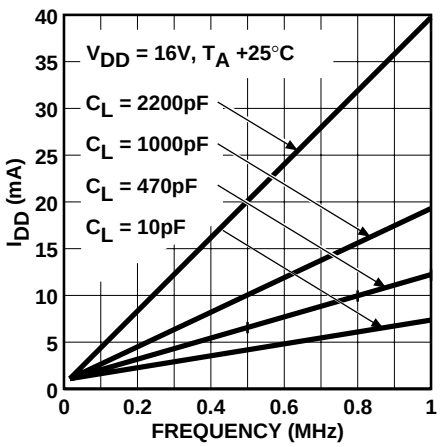
TYPICAL CHARACTERISTICS

Oscillator Frequency vs. C_t and R_t



Supply Current vs. Frequency



Dead Time vs. C_t and Discharge Resistor