CS-361

2MHz Resonant-Mode Control

Description

The CS-361 ia a power supply control IC used in resonant and quasi resonant mode topologies which operate in a Constant Off Time Mode. The IC contains a programmable voltage controlled oscillator (VCO, 2% linearity from 200kHz to 2MHz), a retriggerable one shot and dual high current (1 5A pulse) totem pole outputs

Also included are protective features, such as undervoltage lockout, programmable soft start, and current limiting The CS-360 is pin compatible to the MC34067.

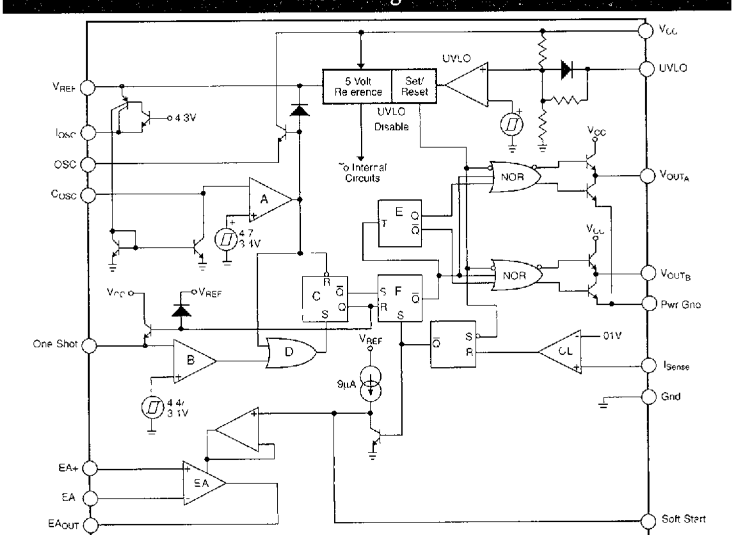
Features

- **Suitable for Zero Voltage Switching**
- **2MHz VCO With User Programmable Min/Max Frequencies**
- **Temperature-Compensated One-Shot**
- **UVLO With Low Start-up Current and Alternative Start/Stop Thresholds**
- **Latched Over-Current Protection**
- **Soft-Start**
- **Low Start–up Current 0.3mA (typ.)**

Absolute Maximum Ratings

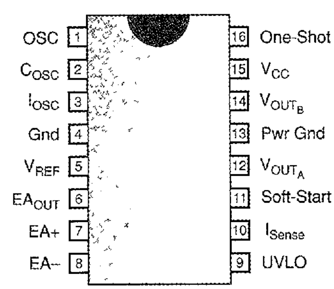
Power Supply Voltage (V_{CC})	20V
Output Current, Source or Sink	
DC	0.3A
Pulse 0 5µs	1.5A
Error Amplifier Input Voltage	–1 to 6V
Current Sense Input Voltage	–1 to 6V
UVLO Input Voltage	–1 to V_{CC}
Reference Output Current	10mA
Power Dissipation (T_A = 50°C)	1W
Junction Temperature	–40°C to 150°C
Storage Temperature	–55°C to 150°C
Lead Temperature (Soldering, 10s)	230°C

Block Diagram



Package Options

16L SO Wide & PDIP



CSC™ CHERRY SEMICONDUCTOR

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Recommended Operating Conditions

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Power Supply Voltage		10	12	18	V
Load Capacitance			1.2	2.5	nF
Error Amplifier Input Voltage		1.5		5 5	V
One-Shot Timing Resistor(R_T)		5	20	50	kΩ
One-Shot Timing Cap (C_T)		200	300	500	pF
Oscillator Timing Cap. (C_{OSC})		200	300	2000	pF
Oscillator Frequency		0 1		2.0	MHz
Ambient Temp. Commercial		0		70	°C
Ambient Temp. Industrial		-25		85	°C

Electrical Characteristics: V_{CC} = 12V, C_{OSC} = 150pF, T_A = -25 to +85°C for the Industrial Version and T_A = 0 to 70°C for the Commercial Version unless otherwise specified.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
■ Reference Section					
Output Voltage	T_A=25°C I_{OUT} = 1mA	5.0	5.1	5.2	V
Line Regulation	10V < V_{CC} < 20V		5	20	mV
Load Regulation	1mA < I_{OUT} < 10mA		5	20	mV
Temperature Stability	(note 1) (0°C < T_A < 70°C)		20	50	mV
Total Output Variation	Line, Load, Temp.	4.9		5.3	V
Output Short Circuit	T_A= 25°C, V_{REF} = 0	20		100	mA
■ Error Amplifier Section					
Input Offset Voltage	V_{EA-} = EA_{OUT}	-15		+15	mV
Input Bias Current	V_{EA-} = V_{EA+} = 2.5V		-0.3	-1.0	µA
Input Offset Current	V_{EA-} = V_{EA+} = 2.5V		0.1	1 0	µA
A_{Vol}		65	90		dB
Common Mode Voltage Range		1.5		5.5	V
Output Sink Current		1.0			mA
Output Source Current		2.0	5.0		mA
Gain Bandwidth Product	(note 1)		2		MHz
V_{OUT} Low			0.7	1 1	V
V_{OUT} High		3.5	3.9	4.3	V
■ VCO Section Note: RMIN = 95.3kΩ, C_{OSC} = 150pF, R_{OSC} = 6.8k, T_A = 25°C unless otherwise noted.					
Minimum Frequency	Error Amplifier Output High	90	100	110	kHz
Freq. Variation over V_{CC} and T_A	Error Amplifier Output High (0°C <T_A<70°C)	85		115	kHz
Maximum Frequency	Error Amplifier Output Low	1.9	2.0	2.1	MHz
V_{peak}			4.8		V
V_{valley}	F_{OSC} = 100kHz		3.6		V
I_{OSC} Pin Input Voltage	I_{OSC} = -400µA	3.3	3.6	4.5	V

Electrical Characteristics: continued

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
■ One-Shot Section Note: C_T = 300pF, T_A = 25°C					
Period Short	R_T = 14.3kΩ	1.43	1 50	1.57	µs
Period Short, Total Variation with V_{CC}, T_A	R_T = 14.3kΩ (0°C<T_A<70°C) 10V < V_{CC} < 20V	1.40	1.50	1.60	µs
Period Long	R_T = 47.5kΩ	4 60	5.00	5.40	µs
Setting Range		0.5		10.0	µs
■ Output Section					
Output Low Level	V_{CC} = 20V				
	I_{SINK} = 20mA		0 25	0.40	V
	I_{SINK} = 200mA		1.50	2.20	V
Output High Level	V_{CC} = 20V				
	I_{SOURCE} = 20mA	18.0	18.5		V
	I_{SOURCE} = 200mA	17.5	18.0		V
Rise Time	T_A=25°C C_{LOAD} = 1nF (note 1)		30	60	ns
Fall Time	T_A = 25°C C_{LOAD} =1nF(note 1)		30	60	ns
■ Current-Limit Section					
Current-Limit Threshold		0 95	1.00	1.05	V
Input Bias Current			1	10	µA
Delay to Output	50mV Overdrive		70	100	ns
■ Soft Start Section					
Charge Current		4.5	9 0	14.0	µA
Discharge Current		0.7	2.0		mA
■ Undervoltage Lockout Section					
Start Threshold	UVLO open	14.5	16.0	17 5	V
Stop Threshold	UVLO open	8	9	10	V
Start Threshold	UVLO = V_{CC}	8	9	10	V
Stop Threshold	UVLO = V_{CC}	7.6	8.6	9.6	V
V_{REF} UVLO threshold		3.7	4 2	V_{REF}	V
Disable Threshold				6	V
UVLO Source Current	UVLO = 0V		200	500	µA
■ Total Supply Current					
Operating (C_{LOAD}=1nF, F_{OSC}=500kHz)			43	50	mA
Start-Up (UVLO Active)	UVLO = V		0.5	0.7	mA

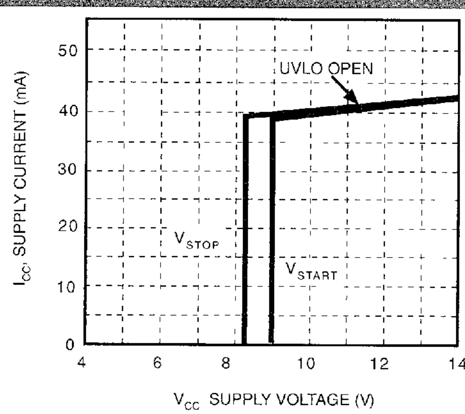
Note 1 Although guaranteed, these parameters are not 100% tested in production

Package Pin Description

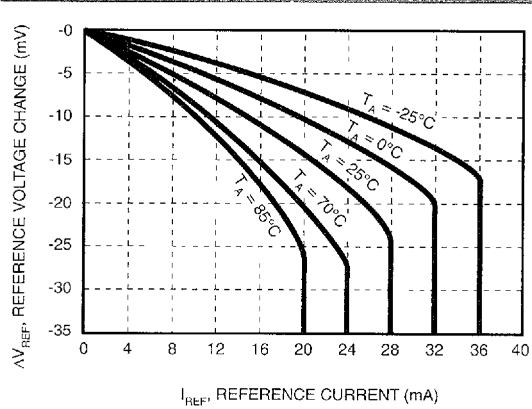
PACKAGE PIN # 16 Lead SO Wide & PDIP	PIN SYMBOL	FUNCTION
1	OSC	Oscillator charge pin. This provides a switched voltage source equal to the reference. It provides charge current for the oscillator capacitance when connected to C_{OSC}.
2	C_{OSC}	Oscillator capacitor, R_{MIN}, and the timing resistor, connect from this node to ground.
3	I_{OSC}	Oscillator control current. Current out of this node to ground appears as discharge current for the oscillator components, determining frequency of operation
4	Gnd	Analog Ground.
5	V_{REF}	Voltage reference output.
6	EA_{OUT}	Output of error amplifier. This output drives R_{OSC} to provide control current to I_{OSC}.
7	EA+	Error amplifier non-inverting input.
8	EA-	Error amplifier inverting input.
9	UVLO	Undervoltage lockout threshold adjust This pin is connected to V_{CC} to enable low voltage start and stop voltage. It is left open for high voltage levels or grounded to disable reference.
10	I_{Sense}	Current limit sense input. The input of a 1V comparator used to sense an over-current condition in the drive circuitry.
11	Soft-Start	External capacitor to ground that determines how fast the output for the error amplifier can rise. (See timing curves for selection.)
12	V_{OUT_A}	Output A drives external transistors.
13	Pwr Gnd	Power Ground.
14	V_{OUT_B}	Output B.
15	V_{CC}	Supply voltage input
16	One-Shot	Resistor and capacitor to ground, set the timing for the one-shot. (See Table 1 for selection.)

Typical Performance Characteristics: continued

Supply Current vs. Supply Voltage

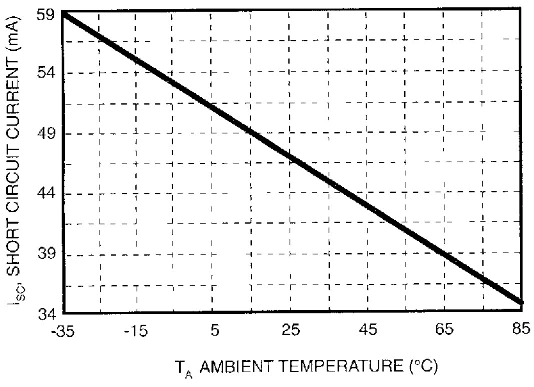


Reference Voltage Change vs. Reference Current Over Temperature

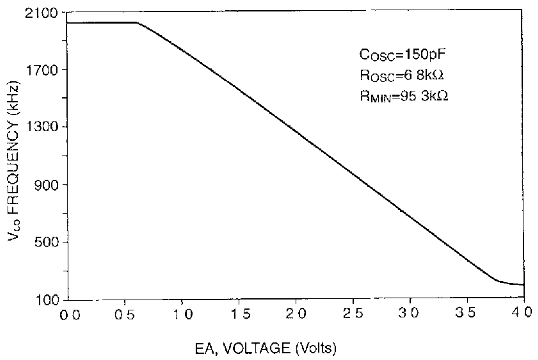


Typical Performance Characteristics: continued

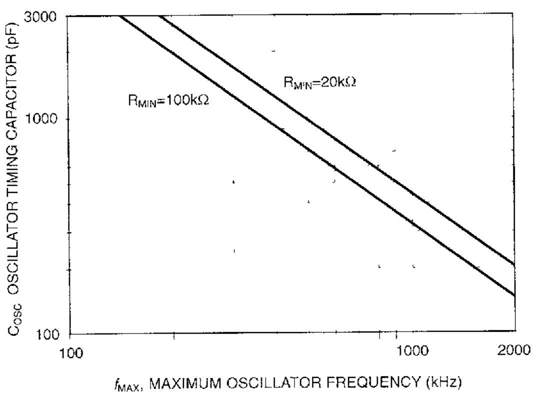
Short Circuit Current vs. Ambient Temperature



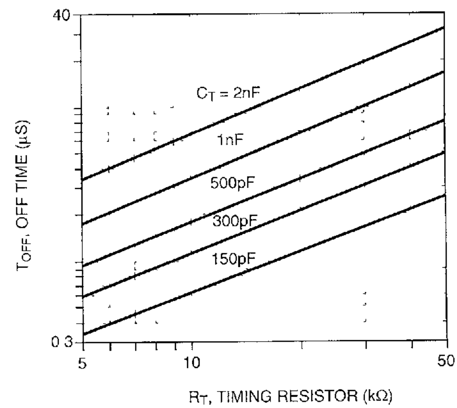
VCO Frequency vs. Error Amplifier Output



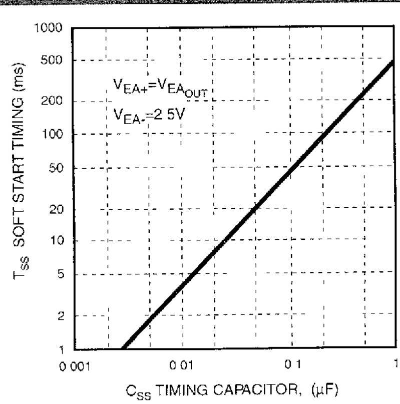
Maximum Clamped Frequency vs. Timing Capacitor Over Timing Resistor



One-Shot Pulse Width vs. Timing Resistor Over Timing Capacitance

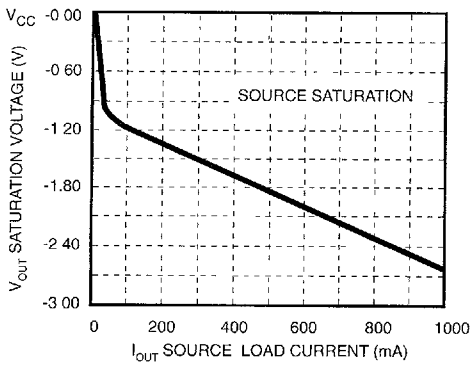


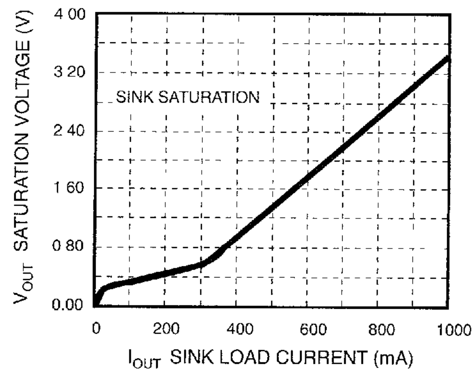
Soft Start Timing vs. Timing Capacitor



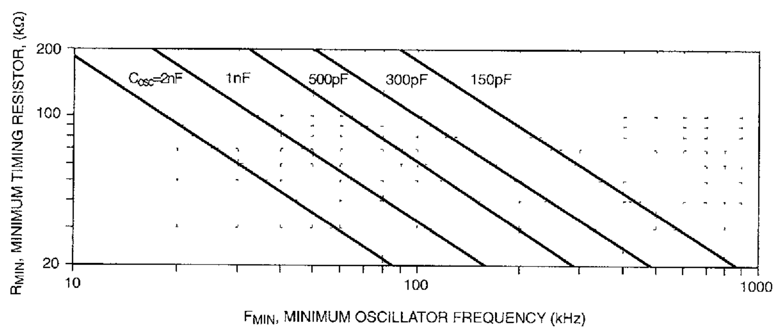
Typical Performance Characteristics: continued

Output Saturation Voltage vs. Load Current

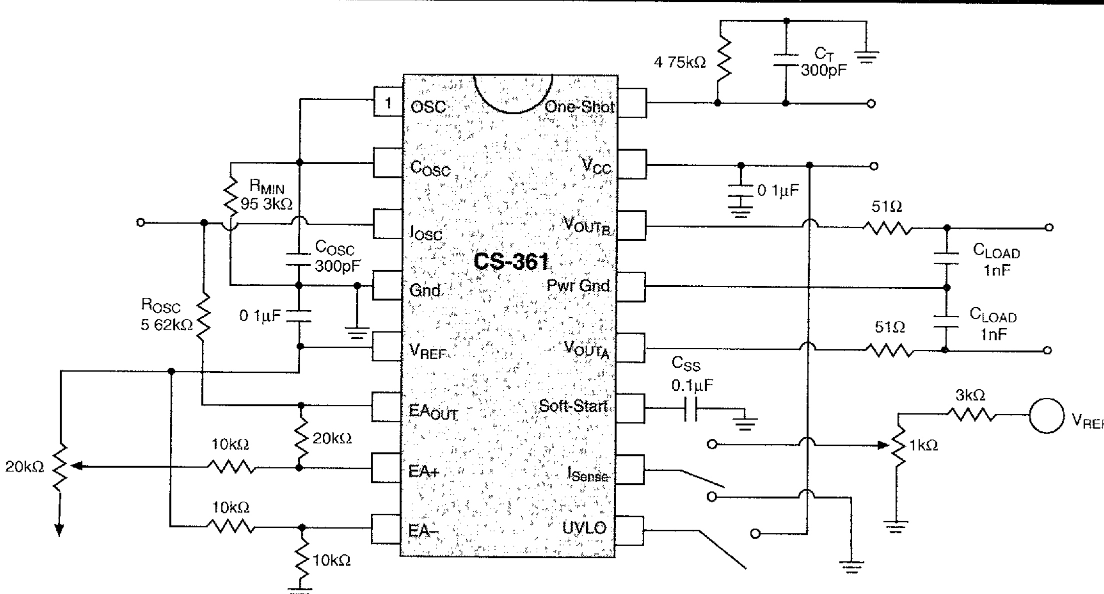




Minimum Clamped Frequency vs. MInimum Timing Resistor Over Timing Capacitor



Test Circuit



Circuit Description

Introduction

The CS-361 is recommended for use in resonant-mode power supplies operating in the zero-voltage-switching (ZVS) mode. The IC regulates the output voltage of a power supply by varying the switching frequency, while holding a constant OFF-TIME (Figure 1). For constant ON-TIME and Constant Duty Cycle applications, please refer to the CS-360 data sheet.

The circuit is principally an oscillator that drives a steering flip-flop (Figure 2). The flip-flop passes the pulses alternately to each of the two output drivers. A programmable One-Shot (B) is used to set the OFF-TIME. Output voltage is sensed at the input of the error amplifier. The output of the error amplifier is connected to the internal current mirror through the R_{OSC} and determines the discharge current of C_{OSC} and hence the frequency and ON-TIME of the outputs. Figure 2 shows a simplified diagram of the VCO and One-Shot sections. External components are included to help explain the operation.

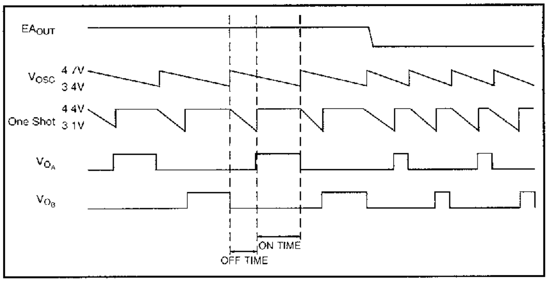


Figure 1: Timing Diagram for CS-361.

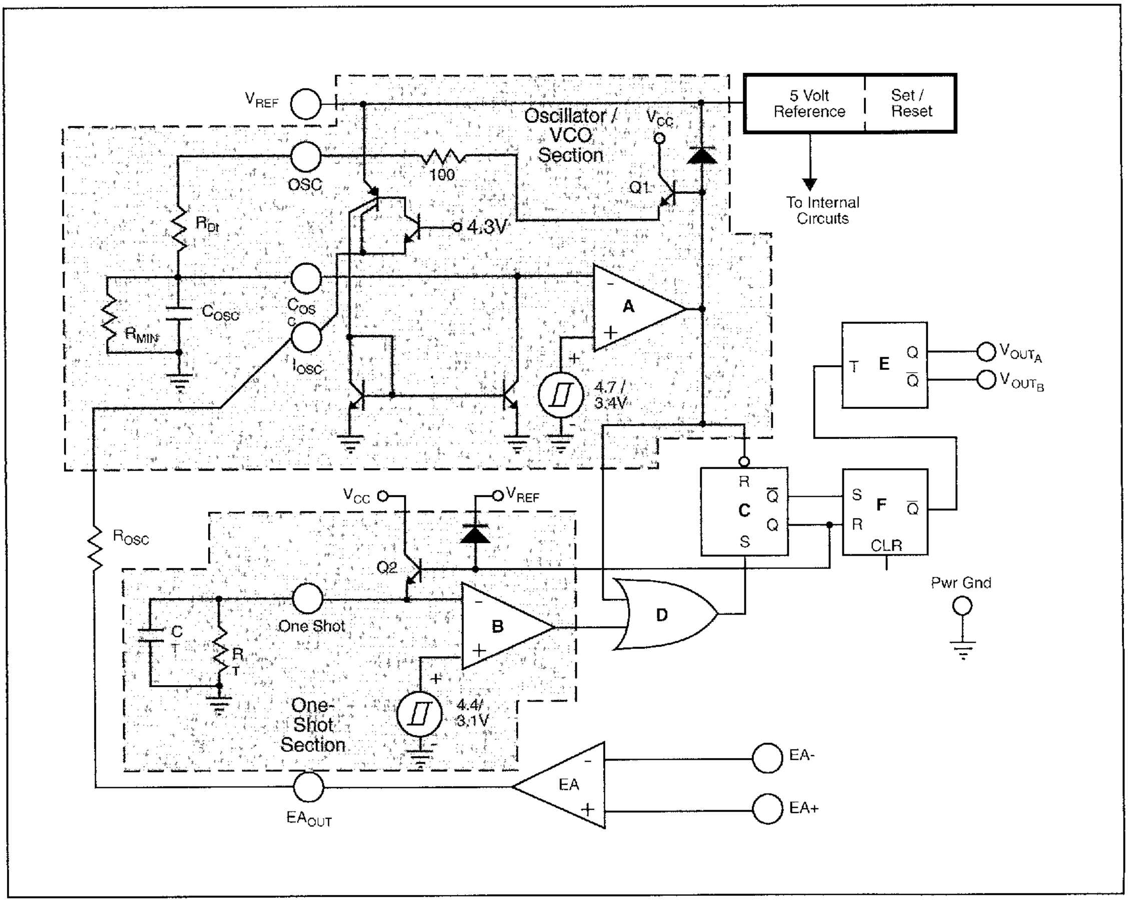


Figure 2: VCO and One Shot section of the CS-361.

Circuit Description: continued

The Oscillator

A window comparator (A) controls the charging and discharging of timing capacitor C_{OSC}. And internal transistor (Q1) charges C_{OSC} through the OSC Charge pin. With the small series resistor this voltage rises quickly, typically in about 70ns. When the voltage on the C_{OSC} pin rises to 4.7 volts, comparator A output becomes low, turning off the charging transistor Q1. The capacitor C_{OSC} discharges through R_{MIN}. This resistor sets the minimum discharge rate and hence the lowest frequency of oscillation. When the voltage across C_{OSC} drops below 3.4 volts, comparator A output becomes high, Q1 turns on again and the next cycle starts.

When the output of comparator A is low it resets Flip-Flop C, turning off both outputs and beginning the OFF-TIME period. At the same time Q2 is turned off, and One-Shot capacitor C_T starts discharging through R_T

Different discharge times for C_{OSC} can be obtained by changing the current of the I_{OSC} pin. Current through this pin is mirrored internally and is used to regulate the discharge rate of C_{OSC}. The maximum I_{OSC} current determines the fastest C_{OSC} discharge time and therefore the highest frequency of oscillation.

One-Shot

The One-shot capacitor C_T value must be such that it discharges faster than the oscillator capacitor C_{OSC}. Capacitor C_T is charged through Q2. When either output is high, Flip-Flop C is set. As the voltage on One-Shot drops below 3.1V, comparator B output becomes high and SETS Flip-Flop C turning on one of the outputs. At the same time Q2 turns on and the One-Shot capacitor charges back to 4.4V This event marks the beginning of ON-TIME. The discharge time of the One-Shot is the OFF-TIME, the time when both outputs are low. This time is fixed by values of C_T and R_T.

One of the outputs continues to remain on as the C_T discharges to the lower threshold voltage. As the voltage on C_{OSC} passes the 3.4V, the comparator A output becomes high and turns on transistor Q1, charging C_{OSC}. As soon as the C_{OSC} voltage passes 4.7V, comparator A's output becomes low, the outputs are RESET, and the next cycle starts. The Toggle Flip-Flop E causes the two outputs to pulse alternately

If the discharge time of the One-Shot B is slower than the C_{OSC} discharge, a RESET is generated before C_T has reached its lower threshold and the frequency of oscillation is determined by the discharge time of the oscillator C_{OSC}. This is not a desirable mode of operation for fixed OFF-TIME mode

Error Amplifier

The Error Amplifier is used to determine the ON-TIME of the regulator. Both inputs and the output of the Error Amplifier are available to the user to allow more flexibility in the choice of feedback and compensation network of the power supply. A resistor (R_{OSC}) is connected between the output of the Error Amplifier and the I_{OSC} pin. The current that flows through R_{OSC} is determined by the output voltage on the Error Amp. This current is internally mirrored and is used to discharge the oscillator capacitor, C_{OSC}. The oscillator runs at a minimum frequency when the output of the Error Amp is high and at the maximum frequency when it is low. The current is R_{OSC} should not exceed 0.5mA in order to preserve the linear relation between error amp. voltage and oscillator frequency

Soft-Start

The soft-start function is implemented by connecting a capacitor, C_{SS} from the Soft-Start pin to ground. This function works by limiting the rise time of the output of the Error Amplifier. The Error Amplifier can rise only as fast as the Soft-Start capacitor can be charged from the internal 9µA current source.

Undervoltage Lockout

The CS-361 has two levels of under-voltage lockout (UVLO). If the UVLO pin is connected to V_{cc} the internal reference is held off until the V_{cc} voltage rises above 9V the reference then remains on as long as the V_{cc} is above 8.6V. If the UVLO pin is left open, the start voltage is 16V and the stop voltage is 9V.

The UVLO pin can also be used for shutdown By connecting UVLO pin to ground the reference and outputs will be disabled.

Current Limit

The CS-361 has a very fast current-limit circuit. If a signal greater than 1V is applied, the I_{Sense} pin will cause the output stages to be latched OFF until the UVLO is cycled. During the current-limit latch the Soft-Start Capacitor is discharged.

Table 1

Charge and discharge times for oscillator capacitor, C_{OSC}:

$t_{chg} = 70ns$

$EA_{OUT} \geq 3.6V$

$$V_d = (V_{R_{OSC}} - V_{EA_{OUT}})\left(\frac{R_{MIN}}{R_{OSC}}\right)$$

$$t_{dis} = R_{MIN} \times C_{OSC} \ln\left(\frac{V_p}{V_v}\right)$$

with $V_p=4.7V$ and $V_v=3.4V$

$t_{dis}=0.32\ R_{MIN} \times C_{OSC}$

$EA_{OUT} < 3.6V$

$$t_{dis} = R_{MIN} C_{OSC} \ln\left(\frac{V_p + V_d}{V_v + V_d}\right)$$

With $EA_{OUT} = 0.7V$ $\quad t_{dis} = (0.029)(95.3k)\ C_{OSC}$

Where $R_{MIN} = 95.3k$, $\quad R_{OSC} = 6.8k$

One-shot capacitor, C_T

$t_{chg} \approx 70ns$

$$t_{dis} = R_T C_T \ln\left(\frac{V_{peak}}{V_{valley}}\right)$$

for $V_{peak}=4.4V$ and $V_{valley}=3.1V$

$t_{dis} = 0.35\ R_T C_T$

Note that: $\quad OFF\text{-}TIME = t_{dis_{ONE\text{-}SHOT}}$

$ON\text{-}TIME = t_{dis_{OSC}} - OFF\text{-}TIME$

Bootstrap Function

When power is initially applied to the CS-361 only the UVLO circuit is active, drawing 300µA (typ) This allows connection of the CS-361 to the high voltage DC bus through a large value resistor. An energy storage capacitor connected from V_{cc} to Gnd of the CS-361 is charged through this resistor as power is initially applied (Figure 3). The value of the capacitor is determined by the amount of energy needed to start the power supply before an auxiliary supply voltage has reached the CS-361 operating voltage. The auxiliary power is usually drawn from the auxiliary winding added to the power transformer or output inductor Note that the larger the value of the soft start capacitor, the longer is takes to power up the power supply and hence the larger the bootstrap capacitor required.

Grounding

There are two ground pins in the CS-361 - one is for power and the other is for logic level signals. These grounds should be connected together at one point on the PCB

Note: Keep high voltage routed separately and high power connections should be as short as possible to minimize radiation.

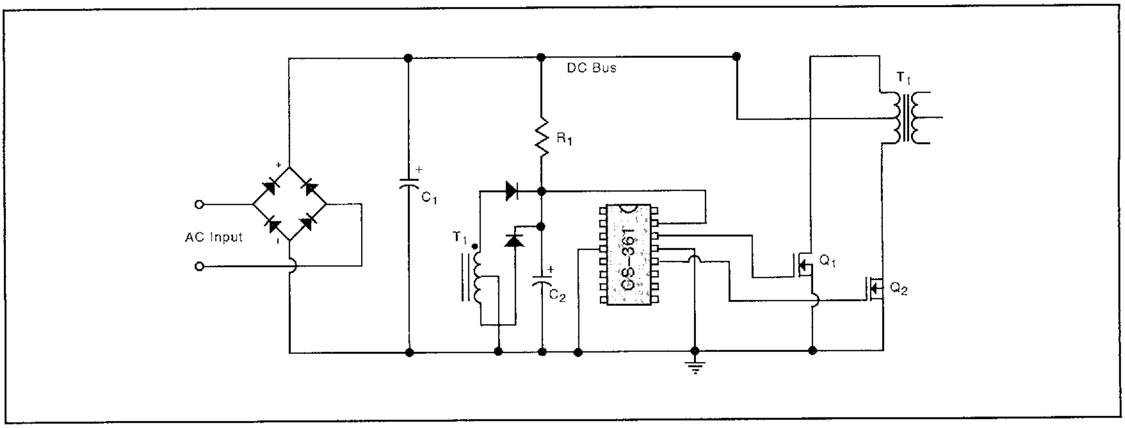


Figure 3: Bootstrap Function

Package Specification

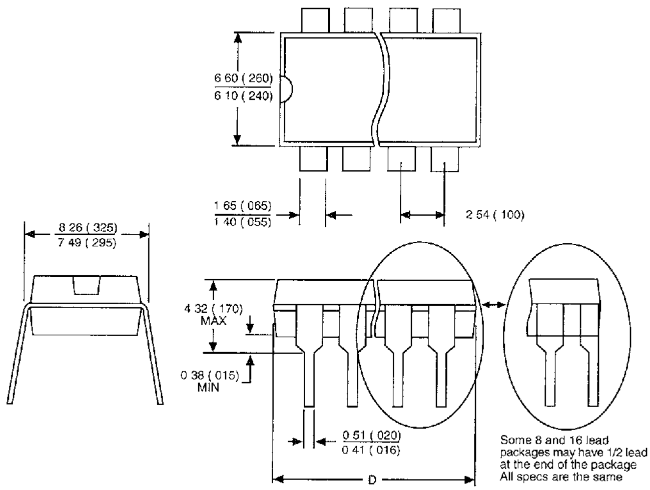
PACKAGE DIMENSIONS IN mm (INCHES)

Lead Count	D			
	Metric		English	
	Max	Min	Max	Min
16 PDIP	19.18	18.92	.755	.745
16 SO Wide	10.46	10.21	.412	.402

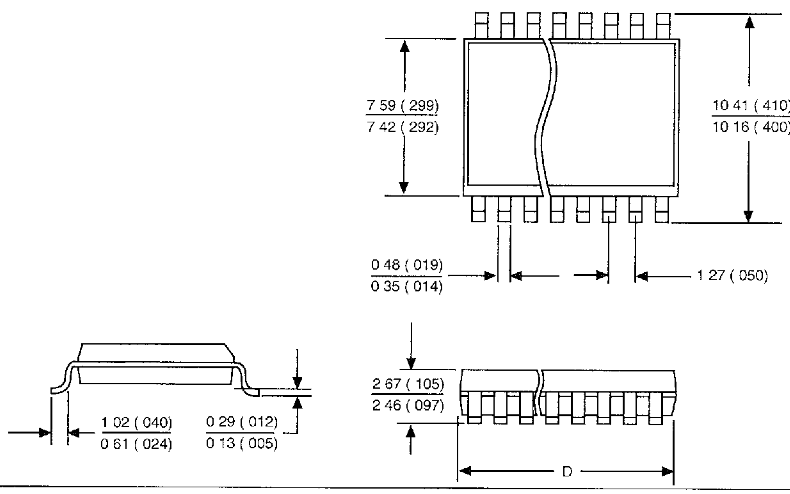
PACKAGE THERMAL DATA

Thermal Data		16L PDIP	16L SO Wide	
$R\Theta_{JC}$	typ	42	23	°C/W
$R\Theta_{JA}$	typ	80	105	°C/W

PDIP: 300 mil wide



SO Wide: 300 mil wide



Ordering Information

Part Number	Description
CS-361N16	16L PDIP
CS-361DW16	16L SO Wide