

CS5101

Secondary Side Post Regulator for AC/DC and DC/DC Multiple Output Converters

The CS5101 is a bipolar monolithic secondary side post regulator (SSPR) which provides tight regulation of multiple output voltages in AC-DC or DC-DC converters. Leading edge pulse width modulation is used with the CS5101.

The CS5101 is designed to operate over an 8.0 V to 45 V supply voltage (V_{CC}) range and up to a 75 V drive voltage (V_C).

The CS5101 features include a totem pole output with 1.5 A peak output current capability, externally programmable overcurrent protection, an on chip 2.0% precision 5.0 V reference, internally compensated error amplifier, externally synchronized switching frequency, and a power switch drain voltage monitor. It is available in a 14 lead plastic DIP or a 16 lead wide body SO package.

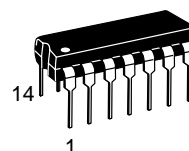
Features

- 1.5 A Peak Output (Grounded Totem Pole)
- 8.0 V to 75 V Gate Drive Voltage
- 8.0 V to 45 V Supply Voltage
- 300 ns Propagation Delay
- 1.0% Error Amplifier Reference Voltage
- Lossless Turn On and Turn Off
- Sleep Mode: < 100 μ A
- Overcurrent Protection with Dedicated Differential Amp
- Synchronization to External Clock
- External Power Switch Drain Voltage Monitor

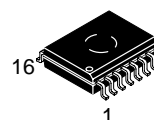


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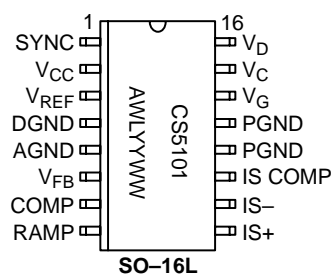
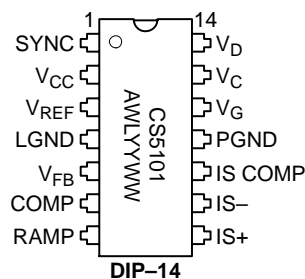


DIP-14
N SUFFIX
CASE 646



SO-16L
DW SUFFIX
CASE 751G

PIN CONNECTIONS AND MARKING DIAGRAMS



A = Assembly Location
WL, L = Wafer Lot
YY, Y = Year
WW, W = Work Week

ORDERING INFORMATION

Device	Package	Shipping
CS5101EN14	DIP-14	25 Units/Rail
CS5101EDW16	SO-16L	46 Units/Rail
CS5101EDWR16	SO-16L	1000 Tape & Reel

CS5101

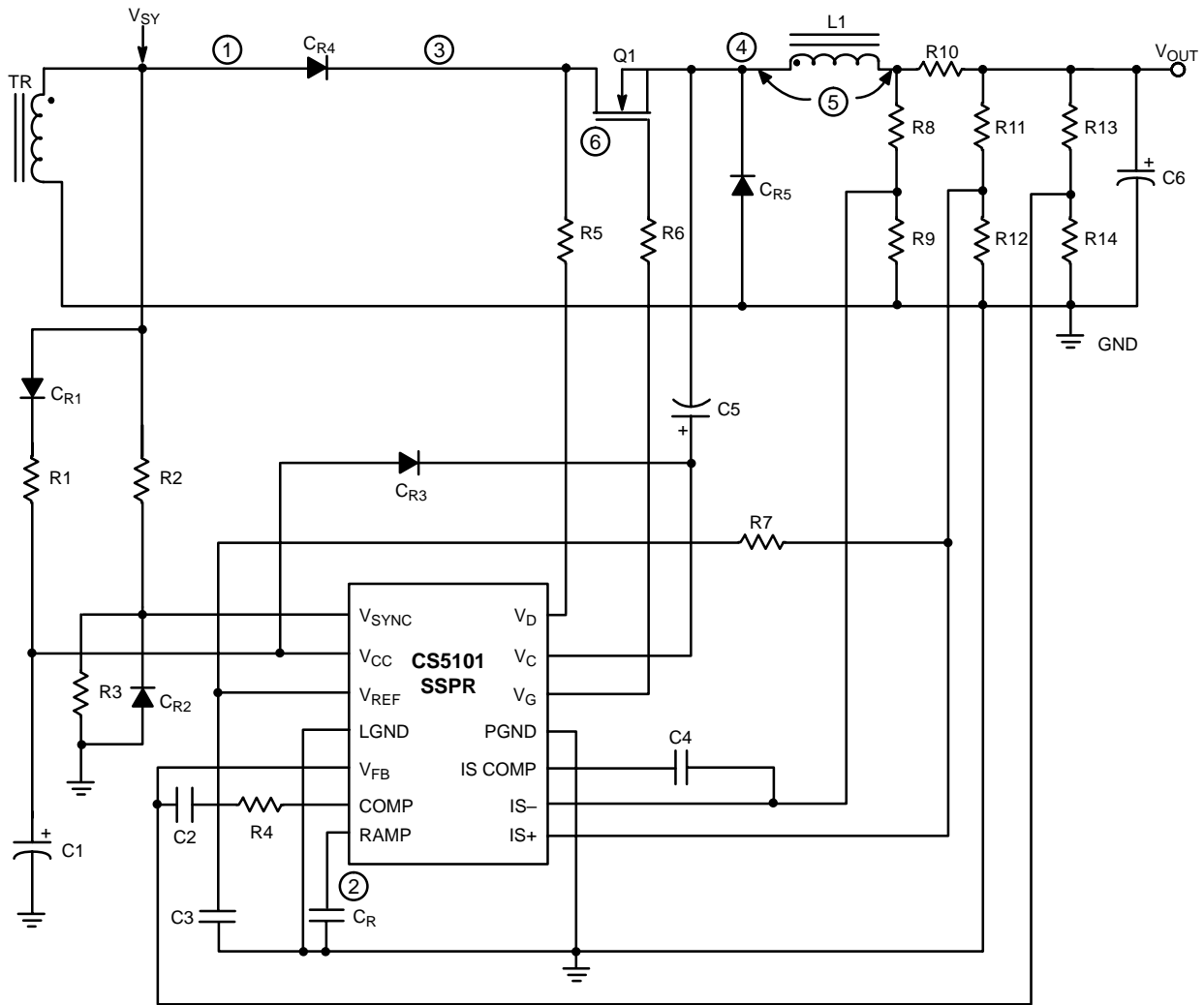


Figure 1. Application Diagram

ABSOLUTE MAXIMUM RATINGS*

Rating	Value	Unit
Power Supply Voltage, V_{CC}	-0.3 to 45	V
V_{SYNC} and Output Supply Voltages, V_C , V_G , V_{SYNC} , V_D	-0.3 to 75	V
V_{IS+} , V_{IS-} ($V_{CC} - 4.0$ V, up to 24 V)	-0.3 to 24	V
V_{REF} , V_{FB} , V_{COMP} , V_{RAMP} , V_{ISCOMP}	-0.3 to 10	V
Operating Junction Temperature, T_J	-40 to +150	°C
Operating Temperature Range	-40 to +85	°C
Storage Temperature Range	-65 to +150	°C
Output Energy (Capacitive Load Per Cycle)	5.0	μJ
ESD Human Body	2.0	kV
Lead Temperature Soldering	Wave Solder (through hole styles only)(Note 1.) Reflow (SMD styles only) (Note 2.)	260 peak 230 peak
		°C °C

1. 10 second maximum

2. 60 second maximum above 183°C

*The maximum package power dissipation must be observed.

CS5101

ELECTRICAL CHARACTERISTICS: ($-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$, $-40^{\circ}\text{C} \leq T_J \leq 150^{\circ}\text{C}$, $10\text{ V} < V_{CC} < 45\text{ V}$, $8.0\text{ V} < V_C < 75\text{ V}$; unless otherwise specified.)

Characteristic	Test Conditions	Min	Typ	Max	Unit
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Error Amplifier

Input Voltage Initial Accuracy	$V_{FB} = V_{COMP}$, $V_{CC} = 15\text{ V}$, $T = 25^{\circ}\text{C}$, Note 3.	1.98	2.00	2.02	V
Input Voltage	$V_{FB} = V_{COMP}$, includes line and temp	1.94	2.00	2.06	V
Input Bias Current	$V_{FB} = 0\text{ V}$, $I_{V_{FB}}$ flows out of pin	–	–	500	nA
Open Loop Gain	$1.5\text{ V} < V_{COMP} < 3.0\text{ V}$	60	70	–	dB
Unity Gain Bandwidth	$1.5\text{ V} < V_{COMP} < 3.0\text{ V}$, Note 3.	0.7	1.0	–	MHz
Output Sink Current	$V_{COMP} = 2.0\text{ V}$, $V_{FB} = 2.2\text{ V}$	2.0	8.0	–	mA
Output Source Current	$V_{COMP} = 2.0\text{ V}$, $V_{FB} = 1.8\text{ V}$	2.0	6.0	–	mA
V_{COMP} High	$V_{FB} = 1.8\text{ V}$	3.3	3.5	3.7	V
V_{COMP} Low	$V_{FB} = 2.2\text{ V}$	0.85	1.0	1.15	V
PSRR	$10\text{ V} < V_{CC} < 45\text{ V}$, $V_{FB} = V_{COMP}$, Note 3.	60	70	–	dB

Voltage Reference

Output Voltage Initial Accuracy	$V_{CC} = 15\text{ V}$, $T = 25^{\circ}\text{C}$, Note 3.	4.9	5.0	5.1	V
Output Voltage	$0\text{ A} < I_{REF} < 8.0\text{ mA}$	4.8	5.0	5.2	V
Line Regulation	$10\text{ V} < V_{CC} < 45\text{ V}$, $I_{REF} = 0\text{ A}$	–	10	60	mV
Load Regulation	$0\text{ A} < I_{REF} < 8.0\text{ mA}$	–	20	60	mV
Current Limit	$V_{REF} = 4.8\text{ V}$	10	50	–	mA
V_{REF_OK} FAULT V	$V_{SYNC} = 5.0\text{ V}$, $V_{REF} = V_{LOAD}$	4.10	4.40	4.60	V
V_{REF_OK} V	$V_{SYNC} = 5.0\text{ V}$, $V_{REF} = V_{LOAD}$	4.30	4.50	4.80	V
V_{REF_OK} Hysteresis	–	40	100	250	mV

Current Sense Amplifier

IS COMP High V	$IS+ = 5.0\text{ V}$, $IS- = IS\text{ COMP}$	4.7	5.0	5.3	V
IS COMP Low V	$IS+ = 0\text{ V}$, $IS- = IS\text{ COMP}$	0.5	1.0	1.3	V
Source Current	$IS+ = 5.0\text{ V}$, $IS- = 0\text{ V}$	2.0	10	–	mA
Sink Current	$IS- = 5.0\text{ V}$, $IS+ = 0\text{ V}$	10	20	–	mA
Open Loop Gain	$1.5\text{ V} \leq V_{COMP} \leq 4.5\text{ V}$, $R_L = 4.0\text{ k}\Omega$	60	80	–	dB
CMRR	Note 3.	60	80	–	dB
PSRR	$10\text{ V} < V_{CC} < 45\text{ V}$, Note 3.	60	80	–	dB
Unity Gain Bandwidth	$1.5\text{ V} \leq V_{COMP} \leq 4.5\text{ V}$, $R_L = 4.0\text{ k}\Omega$, Note 3.	0.5	0.8	–	MHz
Input Offset Voltage	$V_{IS+} = 2.5\text{ V}$, $V_{IS-} = V_{ISCOMP}$	–8.0	0	8.0	mV
Input Bias Currents	$V_{IS+} = V_{IS-} = 0\text{ V}$, I_{IS} flows out of pins	–	20	250	nA
Input Offset Current ($IS+$, $IS-$)	–	–250	0	250	nA
Input Signal Voltage Range	Note 3.	–0.3	–	$V_{CC} - 4.0$	V

3. Guaranteed by design. Not 100% tested in production.

CS5101

ELECTRICAL CHARACTERISTICS: (continued) ($-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$, $-40^{\circ}\text{C} \leq T_J \leq 150^{\circ}\text{C}$, $10\text{ V} < V_{CC} < 45\text{ V}$, $8.0\text{ V} < V_C < 75\text{ V}$; unless otherwise specified.)

Characteristic	Test Conditions	Min	Typ	Max	Unit
RAMP/SYNC Generator					
RAMP Source Current Initial Accuracy	$V_{\text{SYNC}} = 5.0\text{ V}$, $V_{\text{RAMP}} = 2.5\text{ V}$, $T = 25^{\circ}\text{C}$, Note 4.	0.18	0.20	0.22	mA
RAMP Source Current	$V_{\text{SYNC}} = 5.0\text{ V}$, $V_{\text{RAMP}} = 2.5\text{ V}$	0.16	0.20	0.24	mA
RAMP Sink Current	$V_{\text{SYNC}} = 0\text{ V}$, $V_{\text{RAMP}} = 2.5\text{ V}$	1.0	4.0	–	mA
RAMP Peak Voltage	$V_{\text{SYNC}} = 5.0\text{ V}$	3.3	3.5	3.7	V
RAMP Valley Voltage	$V_{\text{SYNC}} = 0\text{ V}$	1.4	1.5	1.6	V
RAMP Dynamic Range	$V_{\text{RAMPDR}} = V_{\text{RAMPPK}} - V_{\text{RAMPVY}}$	1.7	2.0	2.3	V
RAMP Sleep Threshold Voltage	$V_{\text{RAMP}} @ V_{\text{REF}} < 2.0\text{ V}$	0.3	0.6	1.0	V
SYNC Threshold	$V_{\text{SYNC}} @ V_{\text{RAMP}} > 2.5\text{ V}$	2.3	2.5	2.7	V
SYNC Input Bias Current	$V_{\text{SYNC}} = 0\text{ V}$, I_{SYNC} flows out of pin	–	1.0	20	μA

Output Stage

V_G , High	$V_{\text{SYNC}} = 5.0\text{ V}$, $I_{V_G} = 200\text{ mA}$, $V_C - V_G$	–	1.6	2.5	V
V_G , Low	$V_{\text{SYNC}} = 0\text{ V}$, $I_{V_G} = 200\text{ mA}$	–	0.9	1.5	V
V_G Rise Time	Switch V_{SYNC} High, $C_G = 1.0\text{ nF}$, $V_{CC} = 15\text{ V}$, measure 2.0 V to 8.0 V	–	30	75	ns
V_G Fall Time	Switch V_{SYNC} Low, $C_G = 1.0\text{ nF}$, $V_{CC} = 15\text{ V}$, measure 8.0 V to 2.0 V	–	40	100	ns
V_G Resistance to GND	Remove supplies, $V_G = 10\text{ V}$	–	50	100	$\text{k}\Omega$
V_D Resistance to GND	Remove supplies, $V_D = 10\text{ V}$	500	1500	–	Ω

General

I_{CC} , Operating	$V_{\text{SYNC}} = 5.0\text{ V}$	–	12	18	mA
I_{CC} in UVL	$V_{CC} = 6.0\text{ V}$	–	300	500	μA
I_{CC} in Sleep Mode High	$V_{\text{RAMP}} = 0\text{ V}$, $V_{CC} = 45\text{ V}$	–	80	200	μA
I_{CC} in Sleep Mode Low	$V_{\text{RAMP}} = 0\text{ V}$, $V_{CC} = 10\text{ V}$	–	20	50	μA
I_C , Operating High	$V_{\text{SYNC}} = 5.0\text{ V}$, $V_{FB} = V_{IS-} = 0\text{ V}$, $V_C = 75\text{ V}$	–	4.0	8.0	mA
I_C , Operating Low	$V_{\text{SYNC}} = 5.0\text{ V}$, $V_{FB} = V_{IS-} = 0\text{ V}$, $V_C = 8.0\text{ V}$	–	3.0	6.0	mA
UVLO Start Voltage	–	7.4	8.0	9.2	V
UVLO Stop Voltage	–	6.4	7.0	8.3	V
UVLO Hysteresis	–	0.8	1.0	1.2	V
Leading Edge, t_{DELAY}	$V_{\text{SYNC}} = 2.5\text{ V}$ to $V_G = 8.0\text{ V}$	–	280	–	ns
Trailing Edge, t_{DELAY}	$V_{\text{SYNC}} = 2.5\text{ V}$ to $V_G = 2.0\text{ V}$	–	750	–	ns

4. Guaranteed by design. Not 100% tested in production.

CS5101

PACKAGE PIN DESCRIPTION

PACKAGE LEAD #		LEAD SYMBOL	FUNCTION
DIP-14	SO-16L		
1	1	SYNC	Synchronization input.
2	2	V _{CC}	Logic supply (10 V to 45 V).
3	3	V _{REF}	5.0 V voltage reference.
4	–	LGND	Logic level ground (analog and digital ground tied).
5	6	V _{FB}	Error amplifier inverting input.
6	7	COMP	Error amplifier output and compensation.
7	8	RAMP	RAMP programmable with the external capacitor.
8	9	IS+	Current sense amplifier non-inverting input.
9	10	IS–	Current sense amplifier inverting input.
10	11	IS COMP	Current sense amplifier compensation and output.
11	12, 13	PGND	Power ground.
12	14	V _G	External power switch gate drive.
13	15	V _C	Output power stage supply voltage (8.0 V to 75 V).
14	16	V _D	External FET DRAIN voltage monitor.
–	5	AGND	Analog ground.
–	4	DGND	Digital ground.

CIRCUIT DESCRIPTION

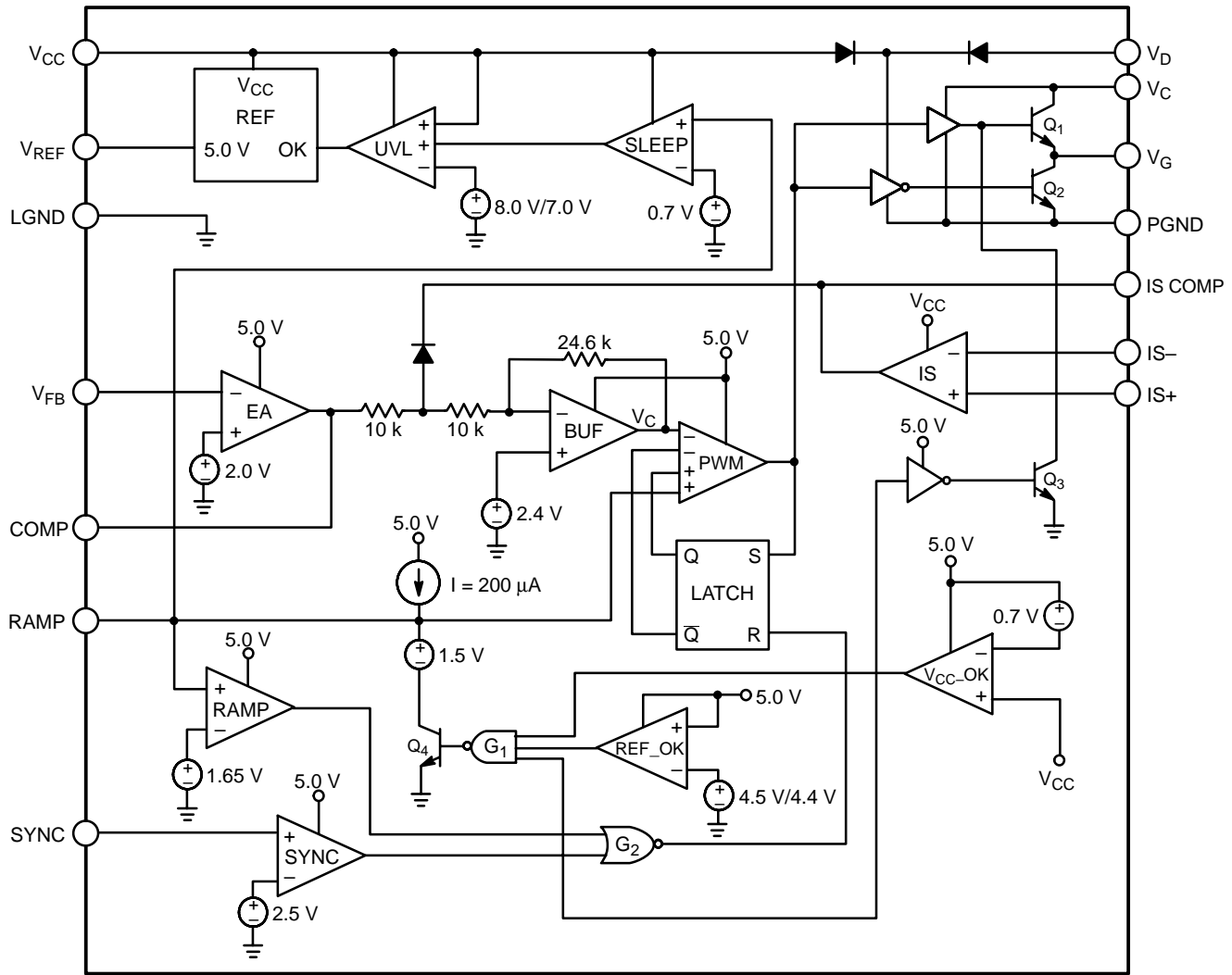


Figure 2. Block Diagram

Theory of Operation

The CS5101 is designed to regulate voltages in multiple output power supplies. Functionally, it is similar to a magnetic amplifier, operating as a switch with a delayed turn-on. It can be used with both single ended and dual ended topologies.

The V_{FB} voltage is monitored by the error amplifier EA. It is compared to an internal reference voltage and the amplified differential signal is fed through an inverting amplifier into the buffer, BUF. The buffered signal is compared at the PWM comparator with the ramp voltage generated by capacitor C_R . When the ramp voltage V_R exceeds the control voltage V_C , the output of the PWM comparator goes high, latching its state through the LATCH, the output stage transistor Q_1 turns on, and the external power switch, usually an N-FET, turns on.

SYNC Function

The SYNC circuit is activated at time t_1 (Figure 3) when the voltage at the SYNC pin exceeds the threshold level (2.5V) of the SYNC comparator. The external ramp capacitor C_R is allowed to charge through the internal current source I (200 μA). At time t_2 , the ramp voltage intersects with the control voltage V_C and the output of the PWM comparator goes high, turning on the output stage and the external power switch. At the same time, the PWM comparator is latched by the RS latch, LATCH.

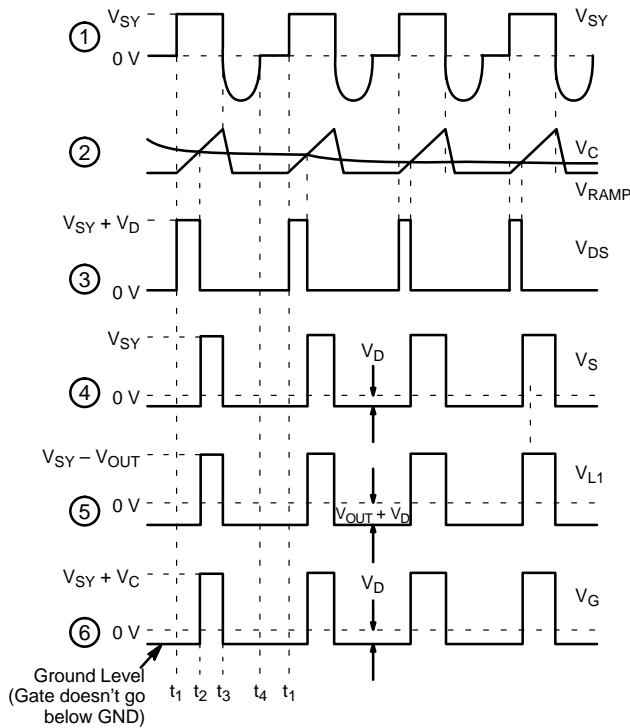


Figure 3. Waveforms for CS5101. The Number to the Left of Each Curve Refers to a Node On the Application Diagram on Page 2.

The logic state of the LATCH can be changed only when both the voltage level of the trailing edge of the power pulse at the SYNC pin is less than the threshold voltage of the SYNC comparator (2.5 V) and the RAMP voltage is less than the threshold voltage of the RAMP comparator (1.65 V). On the negative going transition of the secondary side pulse V_{SY} , gate G_2 output goes high, resetting the latch at time t_3 . Capacitor C_R is discharged through transistor Q_4 . C_R 's output goes low disabling the output stage, and the external power switch (an N-FET) is turned off.

RAMP Function

The value of the ramp capacitor C_R is based on the switching frequency of the regulator and the maximum duty cycle of the secondary pulse V_{SY} .

If the RAMP pin is pulled externally to 0.3 V or below, the SSPR is disabled. Current drawn by the IC is reduced to less than 100 μ A, and the IC is in SLEEP mode.

FAULT Function

The voltage at the V_{CC} pin is monitored by the undervoltage lockout comparator with hysteresis. When V_{CC} falls below the UVL threshold, the 5.0 V reference and all the circuitry running off of it is disabled. Under this condition the supply current is reduced to less than 500 μ A.

The V_{CC} supply voltage is further monitored by the V_{CC_OK} comparator. When V_{CC} is reduced below $V_{REF} - 0.7$ V, a fault signal is sent to gate G_1 . This fault signal, which determines if V_{CC} is absent, works in conjunction with the ramp signal to disable the output, but only after the current cycle has finished and the RS latch is reset. Therefore this fault will not cause the output to turn off during the middle of an on pulse, but rather will utilize lossless turn-off. This feature protects the FET from overvoltage stress. This is accomplished through gate G_1 by driving transistor Q_4 on.

An additional fault signal is derived from the REF_OK comparator. V_{REF} is monitored so to disable the output through gate G_1 when the V_{REF} voltage falls below the OK threshold. As in the V_{CC_OK} fault, the REF_OK fault disables the output after the current cycle has been completed. The fault logic will operate normally only when V_{REF} voltage is within the specification limits of REF_OK.

DRAIN Function

The drain pin, V_D monitors the voltage on the drain of the power switch and derives energy from it to keep the output stage in an off state when V_C or V_{CC} is below the minimum specified voltage.

CS5101

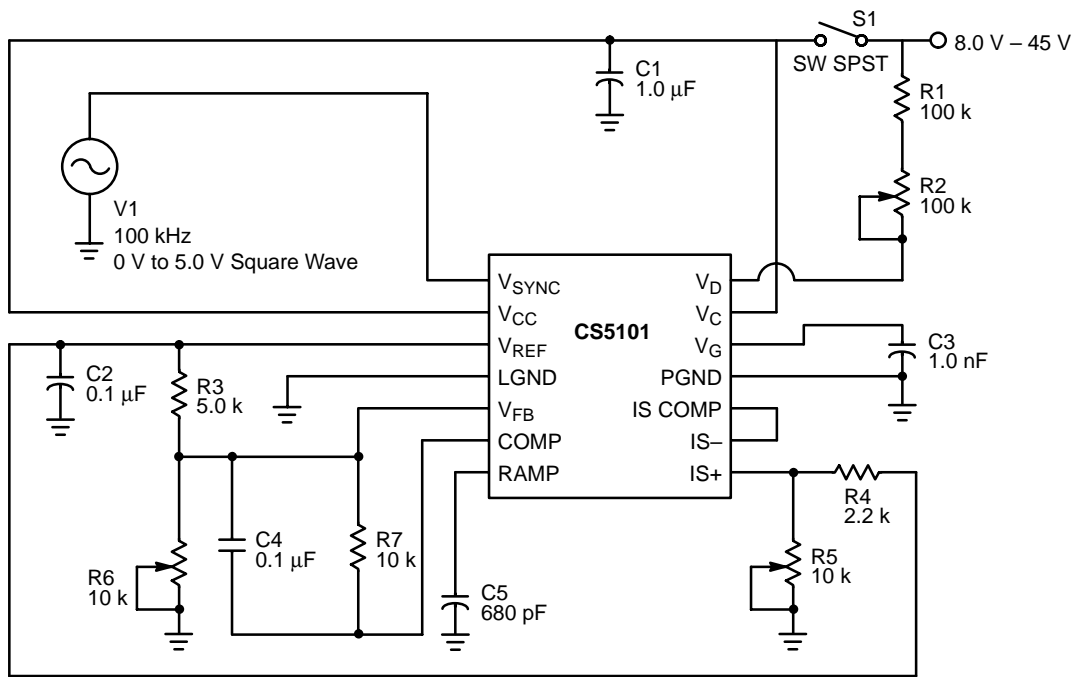
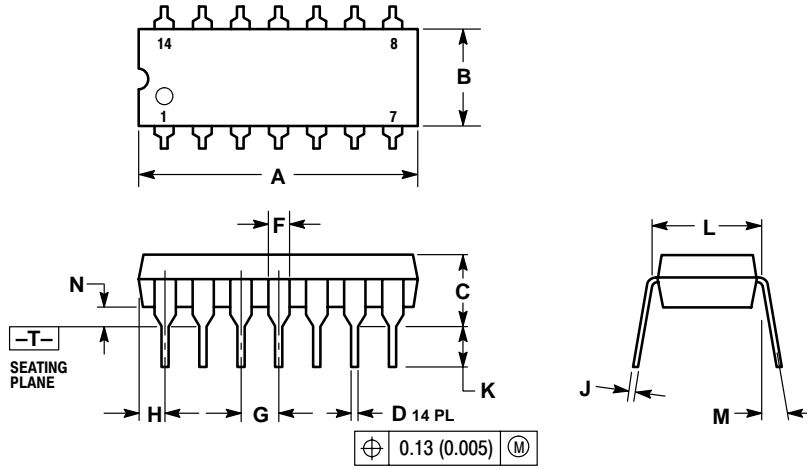


Figure 4. CS5101 Bench Test on DIP-14 Package

CS5101

PACKAGE DIMENSIONS

DIP-14
N SUFFIX
CASE 646-04
ISSUE M

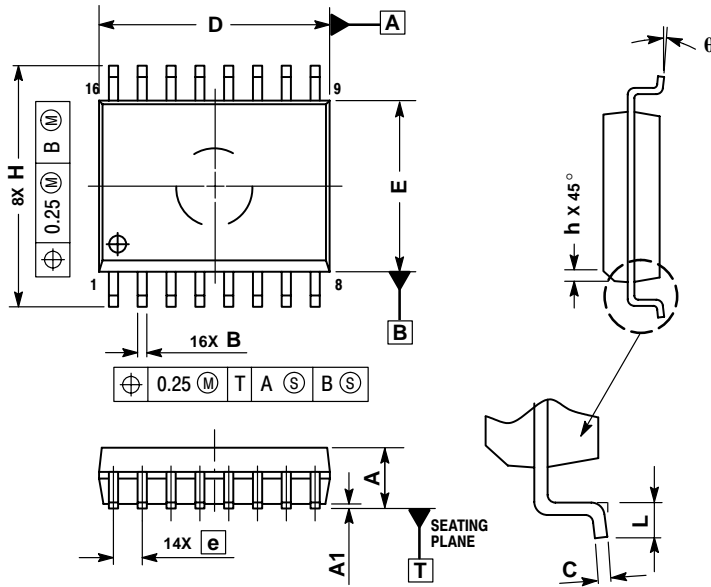


NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION L TO CENTER OF LEADS WHEN FORMED PARALLEL.
4. DIMENSION B DOES NOT INCLUDE MOLD FLASH.
5. ROUNDED CORNERS OPTIONAL.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.715	0.740	18.16	18.80
B	0.240	0.260	6.10	6.60
C	0.160	0.180	4.06	4.57
D	0.015	0.020	0.38	0.51
F	0.040	0.060	1.02	1.52
G	0.100 BSC		2.54 BSC	
H	0.052	0.072	1.32	1.83
J	0.008	0.012	0.20	0.30
K	0.115	0.135	2.92	3.43
L	0.290	0.310	7.37	7.87
M	10 °		10 °	
N	0.020	0.040	0.51	1.02

SO-16L
DW SUFFIX
CASE 751G-03
ISSUE B



NOTES:

1. DIMENSIONS ARE IN MILLIMETERS.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994.
3. DIMENSIONS D AND E DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 PER SIDE.
5. DIMENSION B DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.13 TOTAL IN EXCESS OF THE B DIMENSION AT MAXIMUM MATERIAL CONDITION.


DIM	MILLIMETERS	
	MIN	MAX
A	2.35	2.65
A1	0.10	0.25
B	0.35	0.49
C	0.23	0.32
D	10.15	10.45
E	7.40	7.60
e	1.27 BSC	
H	10.05	10.55
h	0.25	0.75
L	0.50	0.90
θ	0 °	7 °

PACKAGE THERMAL DATA

Parameter		DIP-14	SO-16L	Unit
R _{θJC}	Typical	23	48	°C/W
R _{θJA}	Typical	105	85	°C/W

Notes

Notes

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