CS-8351

Multi-Function Triple Regulator with $\overline{\text{RESET}}$

Description

This multiple output voltage regulator controller is intended for use in microprocessor based, automotive, instrumentation systems which utilize serial gauge drivers. The device contains a 5V, 50mA standby voltage regulator, a 14V pre-regulator which controls an external P-Channel MOSFET pass transistor, a 5V pre-regulator which controls an external PNP pass transistor and a predriver which biases an external PNP operating in the saturation region. The device also contains several I/O ports and a low voltage $\overline{\text{RESET}}$ function.

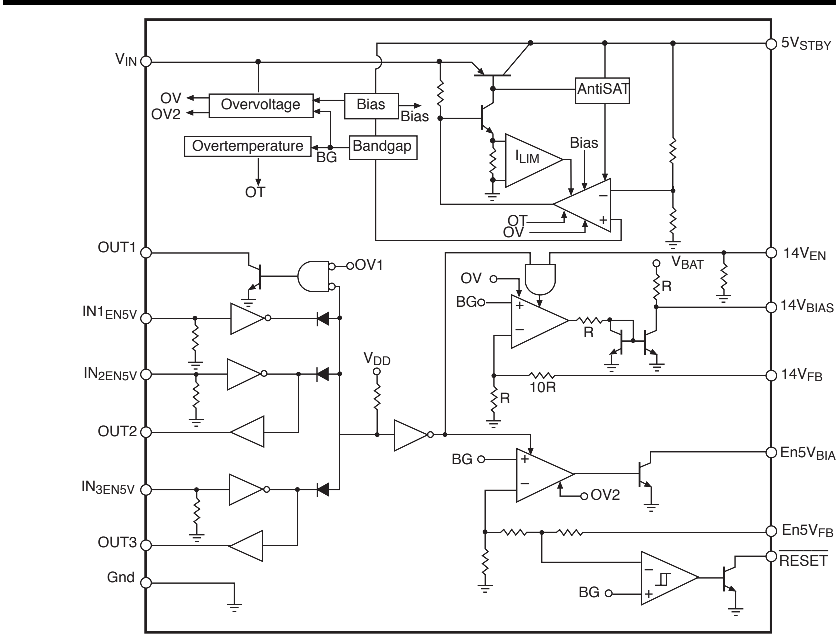
Features

- **5V ±4%, 50mA Voltage Regulator**
- **14V ±5% Pre-Regulator**
- **5V ±2% Pre-Regulator**
- **Power On Reset**
- **I/O Buffers**
- **Thermal Shutdown**
- **Overvoltage Shutdown**
- **High Side Pre-Driver**
- **Low Quiescent Current**
- **$\overline{\text{RESET}}$ and ENABLE Mask Options Available**

Absolute Maximum Ratings

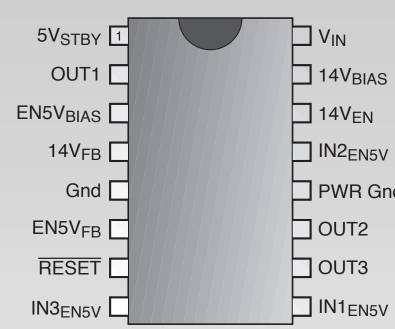
V_{IN}, $IN2_{EN5V}$, $IN3_{EN5V}$, $14V_{BIAS}$, $EN5V_{BIAS}$, OUT1,2,3	-0.3V to 45V
Input Voltage ($14V_{FB}$)	-0.3V to 18V
$5V_{STBY}$, $14V_{EN}$, $\overline{\text{RESET}}$, $EN5V_{FB}$, $IN1_{EN5V}$	-0.3V to 7V
Operating Temperature	-40°C to +105°C
Maximum Junction Temperature	-40°C to +150°C
ESD (Human Body Model)	-2kV to +2kV
Θ_{JA} (16 lead, 300 mil, SOIC)	105°C/W
P_D @ T_A = 105°C	429mW
Lead Temperature Soldering	
Reflow (SMD styles only)	60 sec. max above 183°C, 230°C peak

Block Diagram



Package Option

16 Lead SOIC Wide



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Electrical Characteristics: -40°C ≤ T_A ≤+105°C, -40°C ≤T_J ≤ +150°C, 9V ≤ V_{BAT} ≤ 16V, unless otherwise specified.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
■ General					
Supply Current	Active		4	10	mA
Supply Current	Standby Mode, I($5V_{STBY}$) = 100μA		125	250	μA
■ Standby Regulator (V_{DD})					
Output Voltage	I_{OUT} ≤ 50mA, 7V ≤ V_{BAT} ≤ 26V	4.80	5.00	5.20	V
Current Limit		50	150	225	mA
Overtemperature		160			°C
Overvoltage (OV2)		30	34	38	V
Line Regulation	I_{OUT} = 1mA			50	mV
Load Regulation	V_{IN} = 14V, 50μA ≤ I_{OUT} ≤ 50mA			50	mV
PSRR	V_{IN} = 14V + $1V_{PP}$ @ 120Hz	60			dB
Dropout Voltage	I_{OUT} ≤ 50mA			1.0	V
■ Gauge Driver Pre-Regulator					
V_{OH}, $14V_{BIAS}$	I_{OH} = 100μA			V_{BAT} - 0.5	V
V_{OL}, $14V_{BIAS}$	I_{OL} = 100μA			1.5	V
R_{IN}, $14V_{FB}$			16.75		kΩ
V_{IH}, $14V_{EN}$		2.5			V
I_{IB}, $14V_{EN}$	V_{EN} = 2.5V		25	50	μA
V_{IL}, $14V_{EN}$				0.8	V
Overvoltage Shutdown		16.90	17.75	18.60	V
V_{OUT}		13.4	14.0	14.6	V
■ Switched 5V Pre-Regulator (V_{CC})					
R_{IN}, $EN5V_{FB}$			20		kΩ
I_{OL}, $EN5V_{BIAS}$		12			mA
Overvoltage Shutdown		30	34	38	V
V_{OUT}		4.9	5.0	5.1	V
■ Reset Circuitry					
V_{IH}		4.50		4.85	V
V_{HYS}		10	20	50	mV
V_{OL}	I_{OL} = 8mA, V_{CC} = 4V			1.0	V
	I_{OL} = 2mA, V_{CC} = 4V			0.4	V
	I_{OL} = 100μA, V_{CC} = 1V			0.4	V
	I_{OL} = 100μA, V_{CC} ≥ 1.8V, V_{DD} ≤ 1V			0.4	V
■ High Side Pre-Driver					
V_{OL}, OUT1	I_{OL} = 50mA			1.5	V
Overvoltage Shutdown		30	34	38	V

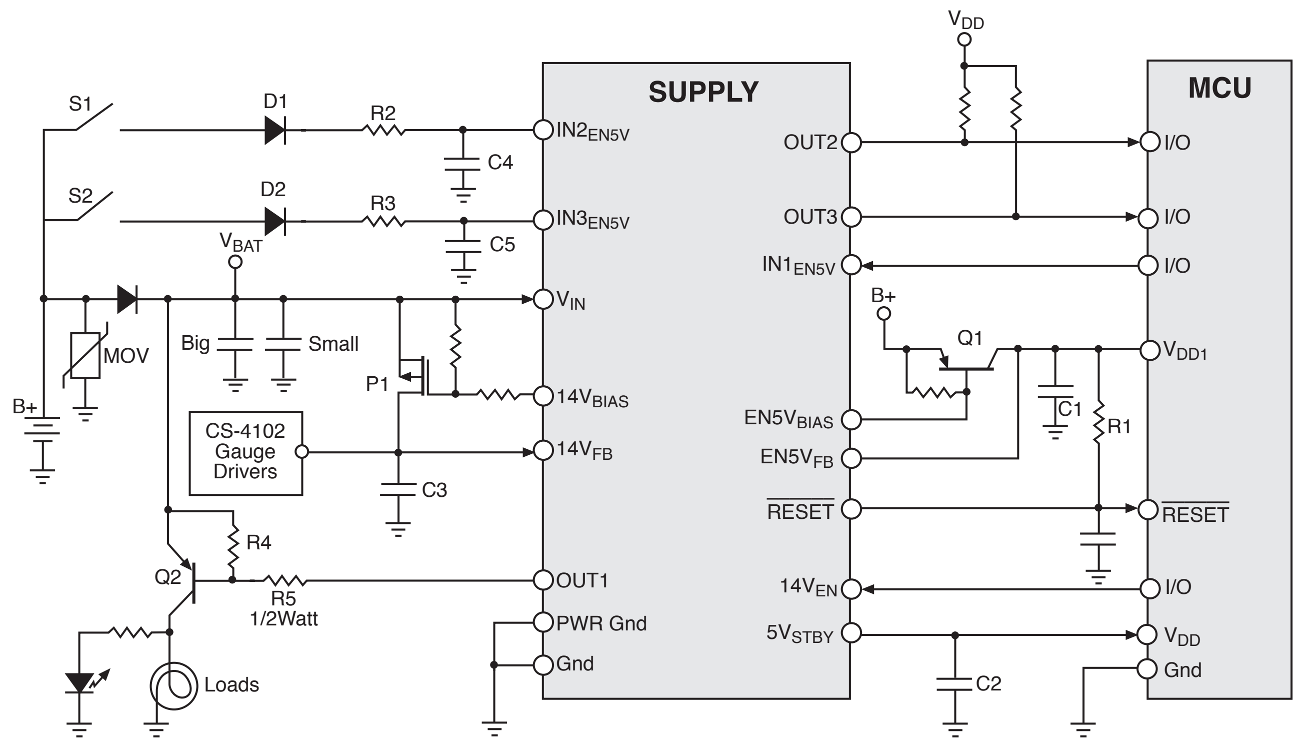
Electrical Characteristics: -40°C ≤ T_A ≤+105°C, -40°C ≤T_J ≤ +150°C, 9V ≤ V_{BAT} ≤ 16V, unless otherwise specified.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
■ I/O Buffers					
V_{IH}, $IN1_{EN5V}$		2.5			V
V_{IH}, $IN2_{EN5V}$		2.5			V
V_{IH}, $IN3_{EN5V}$		2.5			V
V_{IL}, $IN1_{EN5V}$				0.8	V
V_{IL}, $IN2_{EN5V}$				0.8	V
V_{IL}, $IN3_{EN5V}$				0.8	V
V_{OL}, OUT2	I_{OL} = 1mA			0.5	V
V_{OL}, OUT3	I_{OL} = 1mA			0.5	V
I_{IB}, $IN1_{ENEV}$	V_{EN} = 2.5V		25	50	µA
I_{IB}, $IN2_{ENEV}$	V_{EN} = 2.5V		25	50	µA
I_{IB}, $IN3_{ENEV}$	V_{EN} = 2.5V		25	50	µA
R_{IN2}	Pull Down Resistance		160k		Ω
R_{IN3}	Pull Down Resistance		160k		Ω

Package Lead Description

PACKAGE LEAD #	LEAD SYMBOL	FUNCTION
16 Lead SOIC Wide		
1	$5V_{STBY}$	5V standby regulator output voltage.
2	OUT1	Open collector output to bias an external saturated switch.
3	$EN5V_{BIAS}$	5V pre-regulator's output which provides bias to an external PNP transistor.
4	$14V_{FB}$	14V pre-regulator's feedback input which senses the drain voltage on the external P-Channel MOSFET.
5	Gnd	Ground Reference.
6	$EN5V_{FB}$	5V pre-regulator's feedback input which senses the collector voltage on the external P-Channel MOSFET.
7	$\overline{RESET}$	Open collector output which is activated when the $EN5V_{FB}$ voltage drops below the reset threshold voltage.
8	$IN3_{EN5V}$	Input to enable the OUT3 output and the 5V pre-regulator and OUT1.
9	$IN1_{EN5V}$	Input to enable the OUT1 output and the 5V pre-regulator and OUT1.
10	OUT3	Logic level output which is controlled by $IN3_{EN5V}$.
11	OUT2	Logic level output which is controlled by $IN2_{EN5V}$.
12	PWR Gnd	Ground Reference for high current portions of the chip.
13	$IN2_{EN5V}$	Input to enable the OUT2 output and the 5V pre-regulator and OUT1.
14	$14V_{EN}$	Enable input for the 14V pre-regulator. Note: IN1, IN2, or IN3 must also be asserted to enable the 14V pre-regulator.
15	$14V_{BIAS}$	14V pre-regulator's output which provides bias to an external P-Channel MOSFET.
16	V_{IN}	Input supply voltage.

Application Diagram



Note: Fast recovery diodes (D1 and D2) are needed to insure proper operation during negative EMC transients if the inputs are switched battery inputs.

Circuit Description

5V, 50mA Standby Regulator

The standby regulator operates continuously when power is applied to V_{IN}. It is suitable for direct battery connection since it only consumes 250μA with a 100μA load and will withstand a 45V load dump transient and a reverse battery condition. It contains overvoltage shutdown (30V), overtemperature shutdown, and current limit protection. The low voltage reset function can be configured with a mask option to monitor this output voltage.

5V Pre-Regulator

The 5V pre-regulator contains all the necessary circuitry to implement a series pass regulator with the exception of the external PNP pass transistor. The pre-regulator provides 15mA of base drive to the external PNP. It includes the precision matched resistor divider to monitor the output voltage as well as the error amplifier to compare the output voltage to an internal precision voltage reference. The pre-regulator is enabled by either IN1, IN2, or IN3. Its overvoltage shutdown is set to 30V (minimum). The low voltage reset function can be configured with a mask option to monitor this output voltage.

14V Pre-Regulator

This pre-regulator contains all the necessary circuitry to implement a series pass regulator with the exception of an external P-Channel MOSFET. The overvoltage shutdown threshold is set to 16.9V (minimum). The $14V_{EN}$ input activates this regulator. Note: IN1, IN2, or IN3 must also be asserted to enable the 14V pre-regulator.

Low Voltage Reset

The low voltage reset function is configured to monitor the 5V pre-regulator's output voltage. It provides an active low open collector output when the regulator's voltage is below the reset threshold (typically 4.7V).

Mask option: Reset can monitor the 5V standby regulator's output voltage.

50mA Low Side Driver

An open collector Darlington output is provided to bias an external power transistor. This stage is activated when IN1, IN2 or IN3 is asserted. The output is disabled during an overvoltage condition (30V minimum).

Input/Output Buffers

Two level shifting buffers are provided to convert a logic state referenced to battery to a logic state referenced to 5V. OUT2 is controlled by IN2. Out3 is controlled by IN3. The IN2 and IN3 inputs each have an internal 160kΩ pull down resistor. An external resistor divider can be connected to the input to elevate the threshold of the buffer.

5V Standby Regulator

The standby regulator will require a capacitor connected between its output and Ground.

Stability Considerations

The output or compensation capacitor helps determine three main characteristics of a linear regulator: start-up delay, load transient response and loop stability.

The capacitor value and type should be based on cost, availability, size and temperature constraints. A tantalum or aluminum electrolytic capacitor is best, since a film or ceramic capacitor with almost zero ESR can cause instability. The aluminum electrolytic capacitor is the least expensive solution, but, if the circuit operates at low temperatures (-25°C to -40°C), both the value and ESR of the capacitor will vary considerably. The capacitor manufacturers data sheet usually provides this information.

A 10μF capacitor should work for most applications, however it is not necessarily the best solution.

To determine an acceptable value for C_{OUT} for a particular application, start with a tantalum capacitor of the recommended value and work towards a less expensive alternative part.

Step 1: Place the completed circuit with a tantalum capacitor of the recommended value in an environmental chamber at the lowest specified operating temperature and monitor the outputs with an oscilloscope. A decade box connected in series with the capacitor will simulate the higher ESR of an aluminum capacitor. Leave the decade box outside the chamber, the small resistance added by the longer leads is negligible.

Step 2: With the input voltage at its maximum value, increase the load current slowly from zero to full load while observing the output for any oscillations. If no oscillations are observed, the capacitor is large enough to ensure a stable design under steady state conditions.

Step 3: Increase the ESR of the capacitor from zero using the decade box and vary the load current until oscillations appear. Record the values of load current and ESR that cause the greatest oscillation. This represents the worst case load conditions for the regulator at low temperature.

Step 4: Maintain the worst case load conditions set in step 3 and vary the input voltage until the oscillations increase. This point represents the worst case input voltage conditions.

Step 5: If the capacitor is adequate, repeat steps 3 and 4 with the next smaller valued capacitor. A smaller capacitor will usually cost less and occupy less board space. If the output oscillates within the range of expected operating conditions, repeat steps 3 and 4 with the next larger standard capacitor value.

Step 6: Test the load transient response by switching in various loads at several frequencies to simulate its real working environment. Vary the ESR to reduce ringing.

Step 7: Remove the unit from the environmental chamber and heat the IC with a heat gun. Vary the load current as instructed in step 5 to test for any oscillations.

Once the minimum capacitor value with the maximum ESR is found, a safety factor should be added to allow for the tolerance of the capacitor and any variations in regulator performance. Most good quality aluminum electrolytic capacitors have a tolerance of ±20% so the minimum value found should be increased by at least 50% to allow for this tolerance plus the variation which will occur at low temperatures. The ESR of the capacitor should be less than 50% of the maximum allowable ESR found in step 3 above.

5V Pre-Regulator

Since this stage is a pre-regulator, an external pass transistor must be selected to deliver the desired output current, withstand the maximum expected input voltage, and dissipate the resulting power. The base of the external PNP is connected to the $EN5V_{FB}$ lead. The emitter is connected to the battery supply. The collector is connected to the $EN5V_{FB}$ input to feedback the output voltage to the error amplifier.

The base drive output current at $EN5V_{BIAS}$ will be inversely proportional to the output voltage sensed at $EN5V_{FB}$. A capacitor is also required between $EN5V_{FB}$ and ground to provide a stable output voltage. The same procedure can be used to select the capacitor as outlined in the standby regulator section. A pull up resistor is also required between the base and emitter of the PNP. This resistor prevents the external PNP from leaking while the pre-regulator is disabled. It also improves the turn off of the PNP during an overvoltage transient.

14V Pre-Regulator

An external pass transistor is required for this regulator. For automotive applications where the input voltage is typically 14V, an external P-Channel MOSFET is recommended for the pass transistor since it will usually operate as a saturated switch. This occurs when the regulator operates in dropout (i.e. the input voltage falls below the intended regulation voltage). If a PNP were used, excessive base drive current would be required to support the load current since the gain of a saturated PNP is low. The excessive base current needed would develop excessive power dissipation across the CS-8351. Therefore, the P-Channel MOSFET is recommended.

Most P-Channel MOSFETs have a maximum gate to source voltage rating of 15V. Therefore, a resistor divider should be added to the gate as shown in the application diagram. Since the CS-8351 will disable the 14V pre-regulator when the input voltage reaches 18.6V (maximum), the resistor divider should be selected to limit $V_{GS} \leq 15V$ at $V_{IN} = 18.6V$ while providing sufficient gate drive when V_{IN} is low.

A capacitor is required between $14V_{FB}$ and Ground to provide a stable output voltage. The same procedure can be used to select the capacitor as outlined in the standby regulator section.

Applications Information: continued

Low Voltage Reset

$\overline{\text{RESET}}$ Function

A $\overline{\text{RESET}}$ signal (low voltage) is generated as the IC powers up or when V_{OUT} drops out of regulation. A hysteresis is included in the function to minimize oscillations.

The $\overline{\text{RESET}}$ output is an open collector NPN transistor, controlled by a low voltage detection circuit. The circuit is functionally independent of the rest of the IC thereby guaranteeing that the $\overline{\text{RESET}}$ signal is valid for V_{OUT} as low as 1V.

An external RC network on the $\overline{\text{RESET}}$ lead (Figure 1) provides a sufficiently long delay for most microprocessor based applications. RC values can be chosen using the following formula:

$$R_{TOT}C_{RST} = \left[\frac{-t_{Delay}}{\ln\left(\frac{V_T - V_{OUT}}{V_{RST} - V_{OUT}}\right)} \right]$$

where:
- R_{TOT} = R_{RST} in parallel with R_{IN}
- R_{IN} = μP port impedance
- C_{RST} = $\overline{\text{RESET}}$ Delay capacitor
- t_{Delay} = desired delay time
- V_{RST} = V_{SAT} of $\overline{\text{RESET}}$ lead (0.7V @ turn - ON)
- V_T = μP logic threshold voltage
- R_{RST} ≥ 2.7kΩ

Adding C_{RST} will slightly increase the time $\overline{\text{RESET}}$ goes low since the $\overline{\text{RESET}}$ output will have to discharge the energy stored on C_{RST}.

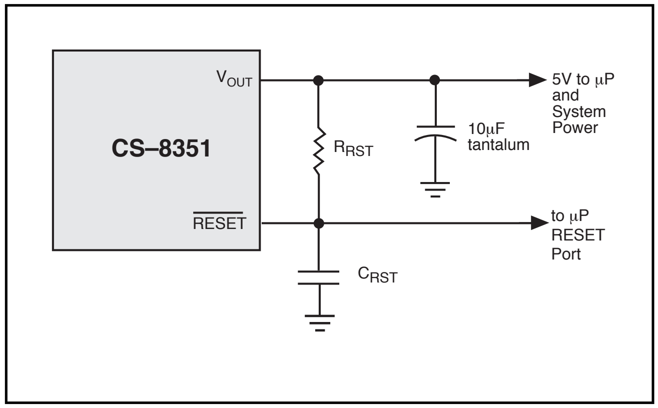


Figure 1. RC Network for $\overline{\text{RESET}}$ Delay.

Package Specification

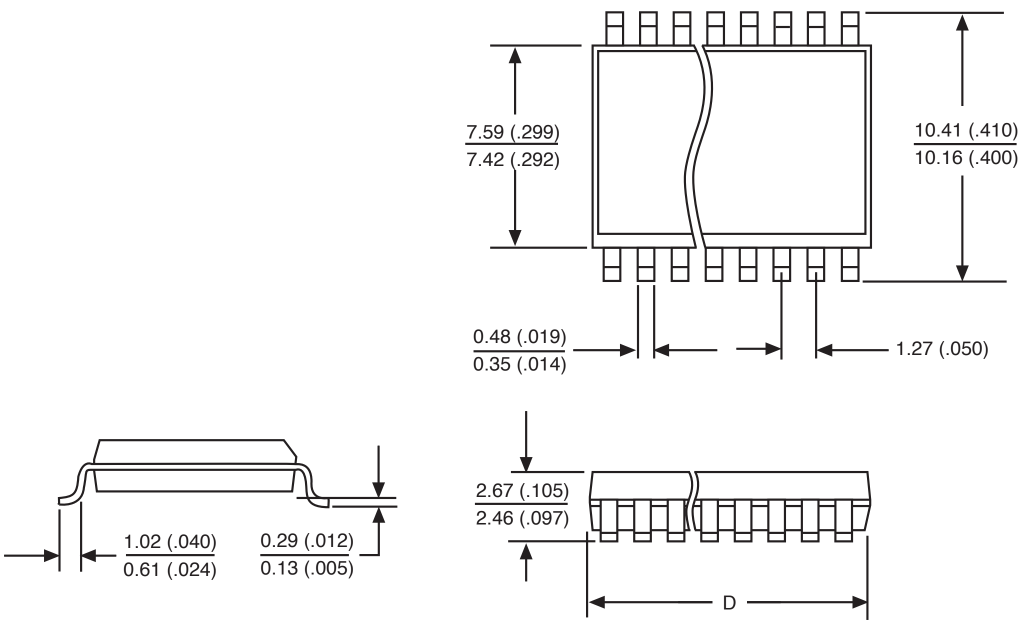
PACKAGE DIMENSIONS IN MM(INCHES)

Lead Count	D			
	Metric		English	
	Max	Min	Max	Min
16L SOIC Wide	10.46	10.21	.412	.402

PACKAGE THERMAL DATA

Thermal Data		16L SOIC Wide	
$R_{\Theta JC}$	typ	23	°C/W
$R_{\Theta JA}$	typ	105	°C/W

16 Lead SOIC Wide (DW); 300 mil wide



Ordering Information

Part Number	Description
CS-8351DW16	16L SOIC Wide
CS-8351DWR16	16L SOIC Wide Tape & Reel

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