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APPLICATION NOTE 5058

5A Step-Down Regulator Has I²C-Programmable Voltage Output

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Abstract: Many portable devices must vary the core voltage of the applications processor dynamically. This design idea shows a simple and effective way to control the voltage output of a 5A step-down regulator, using an I²C interface.

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Many portable devices must vary the core voltage of the applications processor dynamically, to control the voltage-output ramp and also to enable special power-saving modes of operation. The circuit of **Figure 1** shows a simple but effective way to control the voltage output of a 5A step-down regulator, using an I²C interface.

$$V_{OUT} = 0.750 + (I_{DAC} + I_{R4}) \times R3$$
$$I_{DAC} = I_{FS} \times DAC\ VALUE(Dec)/127$$
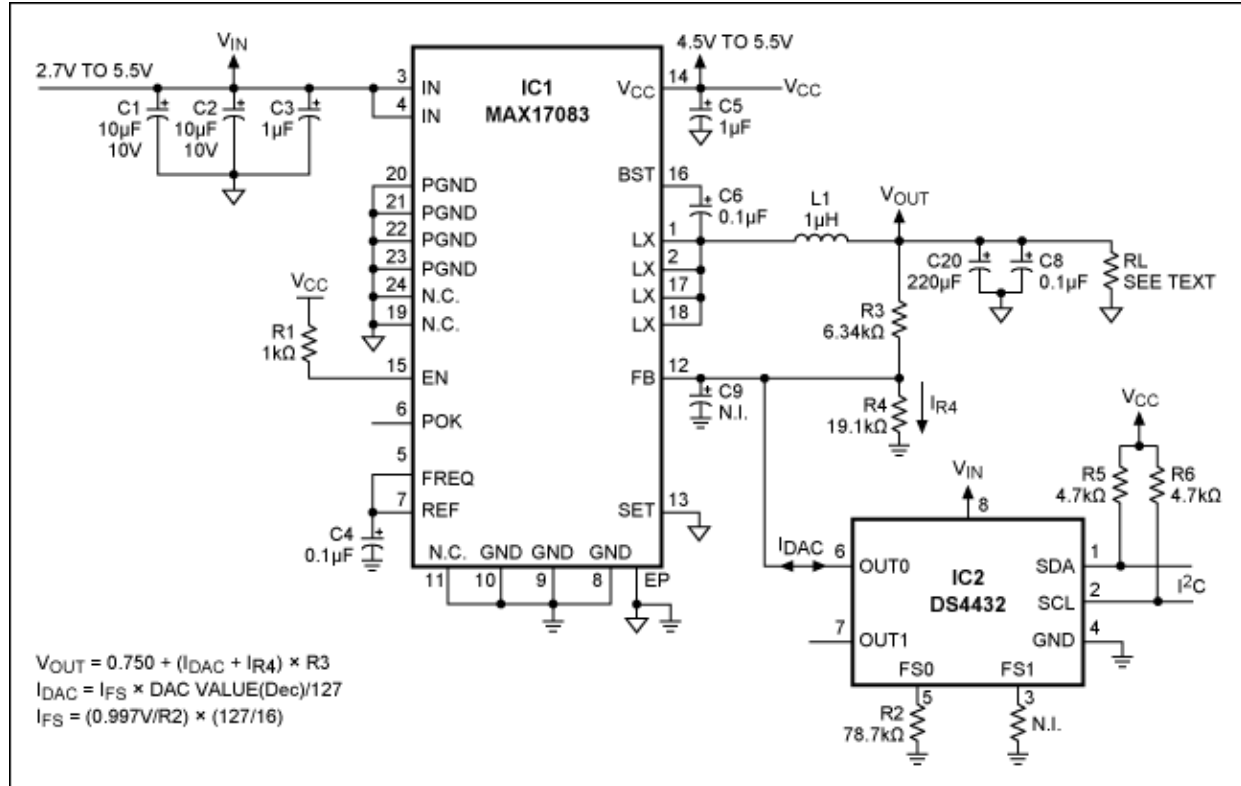$$I_{FS} = (0.997V/R2) \times (127/16)$$

Figure 1. Using the DS4432 I²C-controlled digital-to-analog converter (DAC) to inject current into the feedback node of the MAX17083 step-down regulator enables I²C control of the regulator's output voltage.

The MAX17083 is a high-efficiency, synchronous 5A step-down converter whose 65µA supply current is well suited to portable applications. You can pin-strap the SET pin to VCC, OPEN, REF, or GND, to provide fixed output voltages of 1.8V, 1.5V, 1.1V, or 0.75V. Or with SET connected to GND, you can add a resistive feedback-divider (R3 and R4) that lets you adjust the output to any level between 2.7V and 0.75V, by injecting current at the resistor junction. The values shown for R3/R4 provide a default voltage of 1.0V on power-up, according to the equation $V_{OUT} = 0.750(R3/R4 + 1)$.

For dynamic adjustment of V_{OUT}, a 7-bit current DAC (one-half of the dual DS4432) sinks or sources currents up to 200µA into the feedback node of this divider network. It sinks current to increase the output voltage, and sources current to decrease the output voltage, enabling the I²C interface to select any one of 254 current levels (127 sink and 127 source). Because the DAC output assumes a high-impedance state during power up, the output of the Figure 1 circuit assumes the value determined at that time by R3 and R4 —1.0V in this case.

The full-scale output current for the DS4432 is set by R2 in accordance with the equation found in the *Memory Organization* section of its data sheet: $I_{FS} = (0.997V/R_{FS0}) \times (127/16)$, where $R_{FSO} \equiv R2$ in Figure 1. R2 = 78.7kΩ, which sets the full-scale current to 100.55µA. $R2 = V_{RFS}/(16 \times I_{FS}) \times 127$, where $V_{RFS} = 0.997V$. Based on the values shown for R3 and R4, a full-scale current of 100.55µA was chosen to provide an output-voltage resolution of 5mV.

The voltage-output equation is $V_{OUT} = V_{FB} + (I_{DAC} - I_{R4}) \times R3$, where $V_{FB} = 0.750V$ and $I_{R4} = 0.750/R4$. When $I_{DAC} = 0$, the current through R3 equals the current thru R4. Since the R4 current is always 0.750/R4, we see that any current from I_{DAC} adds to or subtracts from the current through R3. To set the voltage-output resolution to 5mV, therefore, the I_{DAC} LSB must equal 5mV/R3, and the 7-bit I_{DAC}'s full-scale current equals one LSB times 127. The full-scale current in Figure 1 is therefore 127(0.005/6340) = 100.15µA. The value of R2 is 0.997/(16 × 101.15) × 127 = 79,018Ω, and the closest standard-resistor value is 78.7kΩ.

$I_{DAC} = I_{FS} \times$ (DAC value (Dec))/127. You control this output current by writing to address F8H. The format of the data register is as follows:

Sign Bit S: 1 = Source; 0 = Sink	MSB						LSB
S	D6	D5	D4	D3	D2	D1	D0

With no output load, the control range for output voltage is 0.8V to 1.6V. Take note: to improve efficiency for output currents below 100mA, the step-down converter switches automatically to a pulse-skipping mode. While in this mode, it turns off the low-side MOSFET and cannot sink current. With zero load current, if the DS4432 tries to set the output below 0.765V (the no-load value of V_{FB}, from the data sheet), then source current from the I_{DAC} would look like sink current to the MAX17083. Also, the output could become unstable and trigger its overvoltage (OV) or undervoltage (UV) detectors.

To avoid this scenario, you must ensure a minimum load current greater than the DS4432's maximum source current. For example, to set $V_{OUT} = 0.6V$ with zero output load, the sink current into the MAX17083 must be (0.765V - 0.6V)/R3 = 26µA. That is, to enable the MAX17083's output to go below 0.765V in the no-load condition (i.e., to force the MAX17083 to source the necessary current), you need a dummy load (RL in Figure 1) greater than 26µA.

Related Parts

DS4432	Dual-Channel, I²C Adjustable Sink/Source Current DAC	Free Samples

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