

**POWER MANAGEMENT**

The SC632 is a high-current voltage regulator that uses Semtech's proprietary low-noise charge pump technology to maintain a constant 5V output with input voltages ranging from 2.9V to 5.5V. When the input is greater than 5.0V, the device provides the performance of a linear LDO (Low Drop-Out) regulator. For input voltages below 5.0V, the charge pump is activated. The charge pump control system determines whether the device needs to boost the input by 1.5x or 2x to maintain the output at 5.0V based on the input voltage and load current conditions.

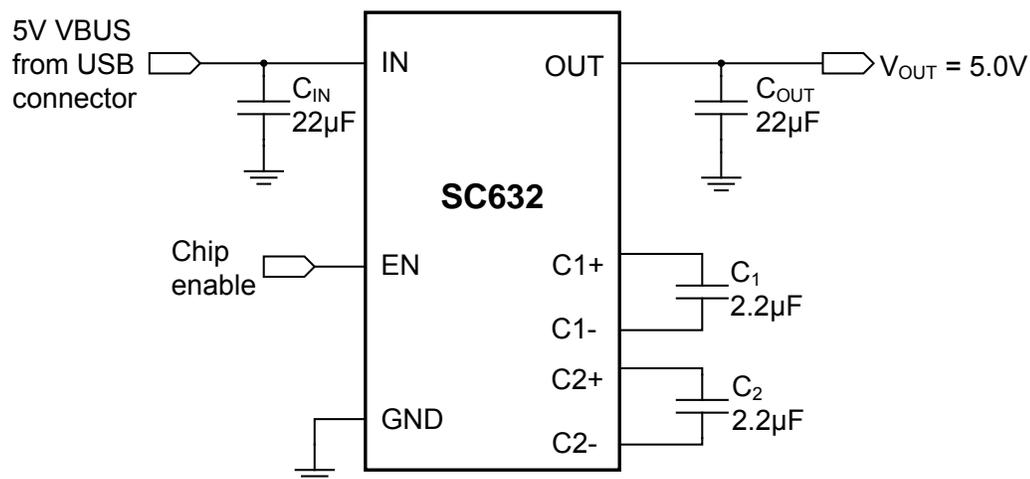
**5V Input to 5V Output**

The inherent function of the SC632 - to provide a 5V output for any input voltage - makes this device especially effective for applications requiring a stable 5V supply. One such application involves taking a loosely-regulated 5V power rail and using it to produce a 5V supply with improved regulation capability. A USB VBUS supply is a good example of such a power rail. The USB specification requires the voltage to be regulated within  $\pm 10\%$  of the nominal value. This means that the 5V supply could droop

as low as 4.5V, making it inadequate for systems that require a well-regulated 5V supply.

Some users faced with this issue will simply regulate the VBUS supply using an LDO regulator as a buffer to produce a stable output. There are some drawback to this approach. In general, the designer must set the output voltage to a level less than the desired 5V to account for the dropout of the LDO. Even when the VBUS supply is higher than 5V, the designer must account for the case when the supply is at 5V or below. A robust design using an LDO would need to set the LDO output voltage less than 4.5V - the minimum supply voltage available. Operating the load at less than 5V is not always an acceptable option.

This application note explains how the SC632 in its standard configuration can be used to provide a stable 5V power rail using a USB VBUS line as the supply. Actual data is used to illustrate the performance of the SC632 in this unique application. The circuit shown in Figure 1 illustrates a typical application for this device.

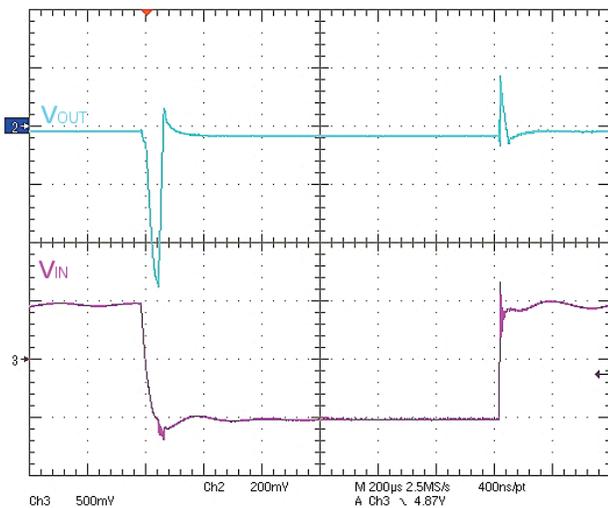


**Figure 1 - Typical Application Circuit for 5V to 5V Regulation**

## Line Transient Response

The first parameter of interest for the 5V-to-5V regulation application is line transient response. This term refers to the output behavior of the SC632 in the presence of a line voltage transient. One example of such a transient is the scenario in which the input supply is a USB hub with several slave devices connected to it. There is a limited amount of supply current available in a hub device, so if there is a large current demand on one slave device the voltage level supplied to all slave devices could decrease rapidly.

The waveforms in Figure 2 illustrate the response of the SC632 when the input voltage drops from 5.5V to 4.5V. The reference point for both waveforms is set to 5V.

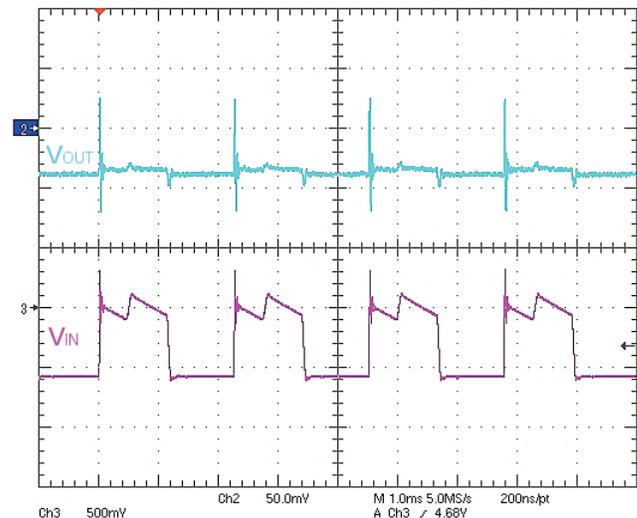


**Figure 2 - Line Transient Response (100mA load)**

The bottom waveform (purple) shows the input supply voltage stepping from 5.5V to 4.5V for a duration of 1.2ms and then back to 5.5V. The SC632 starts in 1x (LDO) mode in this scenario because the input supply is larger than required to supply 100mA at the 5V output voltage level. The top waveform (blue) shows how the output is maintained at approximately 5V until the input voltage drops. During the fall time, the output voltage tracks the input until the charge pump is activated. This process takes approximately 40µs before the charge pump engages and the output is boosted back to 5V. Once the output voltage is returned to a level at which the charge pump is no

longer needed, the charge pump is automatically disabled and 1x mode is restored.

Figure 3 illustrates SC632 performance when the input supply varies between a noisy 5V level and a fixed 4.5V, as shown by the bottom waveform (purple). The reference point for both waveforms is set to 5V.



**Figure 3 - Line Transient Steady State Response (100mA load)**

In this case, the top waveform (blue) shows the SC632 has activated the charge pump in 1.5x mode to maintain the output at 4.96V under load. Note that, aside from some minor effects of switching transients, the output voltage is regulated to 5V regardless of the input supply level. The transients on the output waveform are between 50mV and 100mV, or 1-2%, which is well within the voltage regulation requirements. Figure 3 also illustrates that the SC632 rejects the noise on the 5V supply to provide a cleaner 5V output, which is important for noise-sensitive circuits such as those found in modems and other communications equipment.

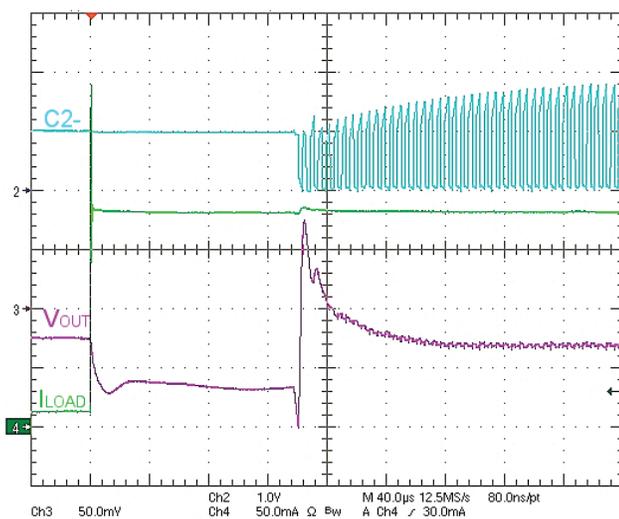
In the steady state response, regulation is maintained to within the  $\pm 3\%$  range specified in the datasheet - even during the transient events. If a linear LDO regulator had been used, the device would have experienced drop out while the supply was at 4.5V, which means the output would have been unregulated and equal to the input

supply voltage minus the I-R drop of the device. The SC632 maintains regulation during the low-voltage duration so that the load can perform without loss of data.

### Load Transient Response

Like line transients, load transients can adversely affect regulation by putting a sudden current load demand on the regulator. In systems using the VBUS 5V supply from a USB master, it is not uncommon for the slave device to have a large step in load current that can cause the 5V supply to droop. In such situations, it is important to recover quickly from this event and maintain proper regulation even while the supply voltage has sagged below the expected 5V level.

The waveforms in Figure 4 show how the SC632 performs under these conditions with its input supply fixed at 5.0V. The stepped waveform (green) shows the load current being switched from 10mA to 180mA. The top waveform (blue) monitors the C2- pin voltage to show when the charge pump is activated. The charge pump is active when a switching waveform appears. The bottom waveform (purple) illustrates the output voltage response during this stepped load event. The output sags to approximately 4.93V for 140 $\mu$ s until the charge pump is engaged and regulation is restored. The entire event takes less than 200 $\mu$ s to restore regulation to expected levels.



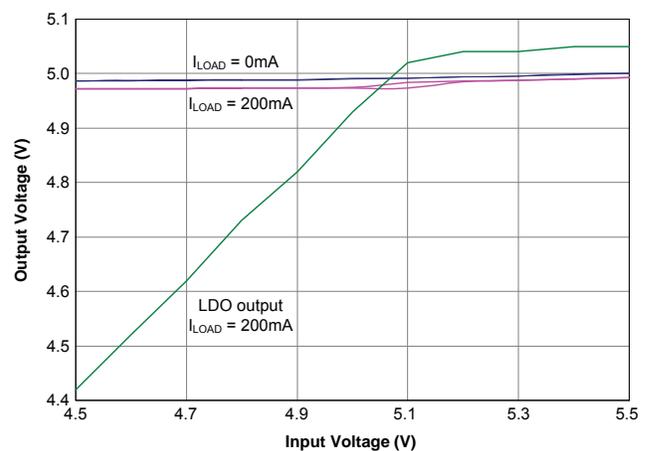
**Figure 4 - Load Step Response**

### Line and Load Regulation

Another possible application scenario involves an input that varies widely over a specified range. For example, in the case of a USB slave device that requires a regulated 5V, it cannot expect that all masters have the same regulation requirements designed into their power supply. In some cases, the VBUS supply can be a tightly regulated 5V, but in others it can be a poorly regulated supply that experiences drops in voltage as the load current demand changes. Two parameters that describe the SC632's ability to adapt to this behavior are line regulation and load regulation.

### Line Regulation Performance

When a varying input supply is used, the SC632 can provide a buffer by filtering out changes in line voltage. In the plot shown in Figure 5, the input supply voltage is varied from 4.5V to 5.5V and then back to 4.5V. Note that the device switches modes during these transitions without affecting the value of the output voltage.



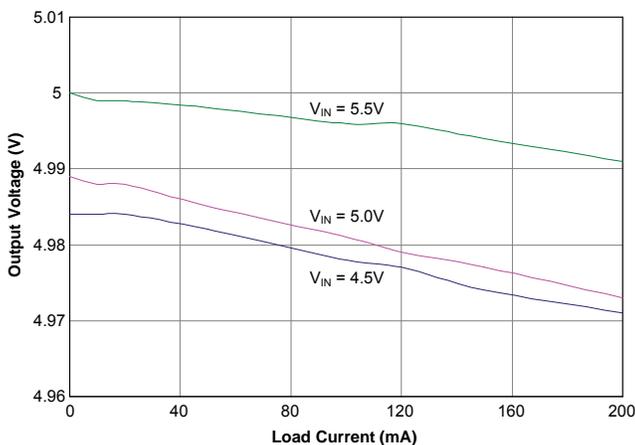
**Figure 5 - Line Regulation Performance**

The data in Figure 5 illustrates how effective the SC632 is at maintaining the output voltage even as the input supply varies. The output voltage never drops below 4.97V. Note that the curve for the 200mA load condition also shows regulation during LDO mode and charge pump mode with hysteresis clearly displayed. This hysteresis is used to keep the charge pump active as long as necessary to ensure regulation is maintained and avoid mode tog-

gling that can cause unwanted transient noise. By comparison, an LDO would not be able to provide the same level of line regulation when the input voltage dropped below 5.1V. The sloping waveform (green) shows data collected using an LDO as the supply in the same scenario.

### Load Regulation Performance

Another parameter that illustrates the SC632 regulation capability is load regulation. This parameter quantifies the amount of output voltage variation as the load current increases. Figure 6 illustrates the load regulation performance of the SC632 with the load current increased from 0mA to 200mA and the input supply set to 3 different settings: 4.5V, 5V, and 5.5V.



**Figure 6 - Load Regulation Performance**

As with line regulation, the SC632 maintains the output voltage above 4.97V even when the load is 200mA and the input voltage is 4.5V. This capability is especially critical when the output voltage is supplying equipment that requires a 5V power supply to ensure proper data transfer or processing.

### Other Considerations

The SC632's simplicity is what makes it an ideal device to provide 5V buffering capability. Figure 1 illustrates how a circuit using the SC632 device and four external capacitors satisfies this application. It is important to use the capacitance values recommended in the datasheet to ensure proper regulation. When PCB area is not a concern, the largest practical capacitance size should be used to ensure the actual capacitance matches the nominal capacitor values.

Proper low-noise layout techniques should always be followed as well. The SC632 datasheet provides a detailed list of layout guidelines that will help ensure that device performance is optimized. Compromising on these layout guidelines could result in reduced performance of the circuit and increased susceptibility to surrounding noise.

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