3mm × 3mm QFN IC Directly Monitors 0V to 80V Supplies: Features I²C Interface, Peak Value Tracking and Runs from Any Supply

CY Lai

Power monitoring in combination with control mechanisms can significantly boost system energy efficiency and reliability. The LTC2945 is a highly integrated digital power monitoring solution that is compact, rugged and easy-to-use. It is designed to fit applications requiring power monitoring with a minimal number of components.

Figure 1 shows the LTC2945's functional block diagram. All basic elements required for power monitoring are integrated, including a precision current sense amplifier, precision resistive dividers, an analog-to-digital converter (ADC) and an I²C interface for communicating with the host controller. Only an external current sense resistor is required. The host can periodically poll the LTC2945 for available power data, minimum and maximum values are stored, and an alert can be sent from the LTC2945 to interrupt the host when measured values exceed their preprogrammed limits.

MONITOR POWER ON ANY SUPPLY

The LTC2945's internal current sense amplifier features a common mode range of 0V to 80V to suit a wide variety of high side and low side current sensing applications. Most wide range supply monitors available today require a low voltage secondary supply for operation, which can be undesirable for several reasons:

- There is no suitable secondary supply
- The secondary supply, often loaded with noisy digital circuits, must be sufficiently filtered or bypassed due to the finite power supply rejection ratio of the supply monitor at higher frequencies
- The secondary supply exists, but is not readily accessible—it is inconveniently located on the printed circuit board, complicating the routing of a power line

The LTC2945 avoids these problems by integrating a high voltage linear regulator that can be powered directly from 4V to 80V supplies. The output of the linear regulator ($INTV_{CC}$) powers the LTC2945, and can be externally bypassed to prevent supply noise from corrupting the signal integrity of internal circuitry. The linear regulator is capable of supplying a 10mA load, saving the cost of a dedicated high voltage linear regulator needed to power circuits such as opto-couplers in some applications.

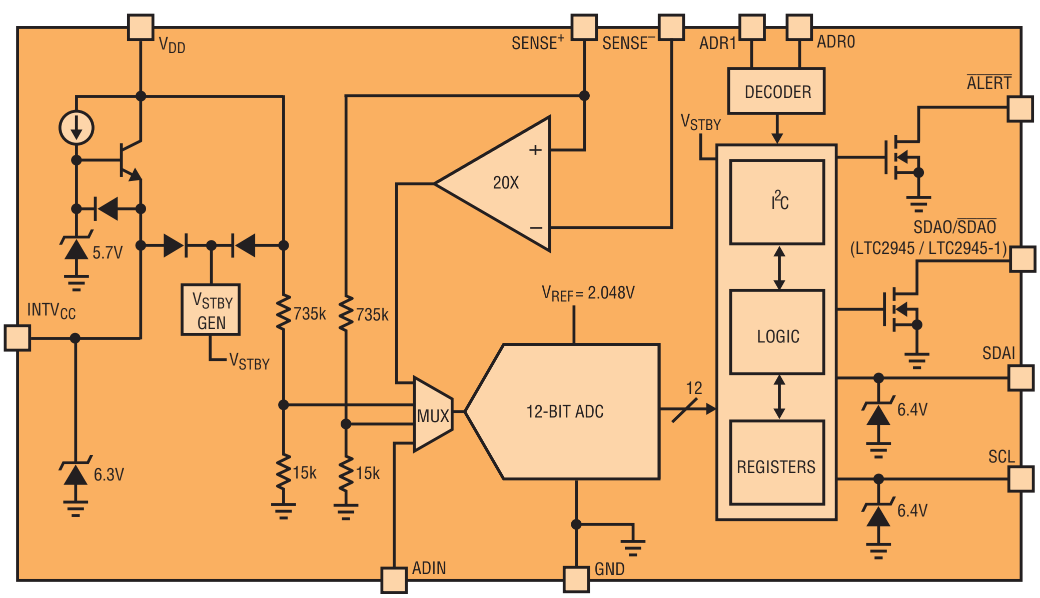


Figure 1. Functional block diagram of the LTC2945

The LTC2945 is a highly integrated power monitor that easily fits into a wide range of systems. It offers a 0V to 80V common mode range, 2.7V to 80V operating range, ±0.75% accurate voltage and current measurements, and an on-chip digital multiplier that computes power.

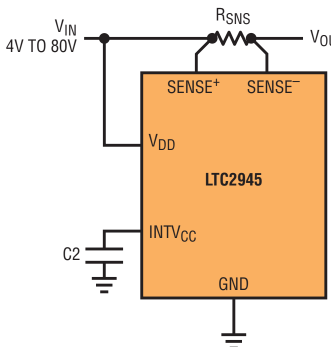


Figure 2a. The LTC2945 deriving power from the monitored supply

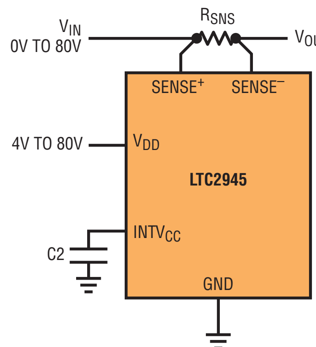


Figure 2b. The LTC2945 deriving power from a wide ranging secondary supply

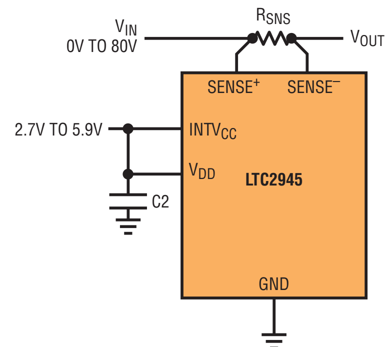


Figure 2c. The LTC2945 deriving power from a low voltage secondary supply

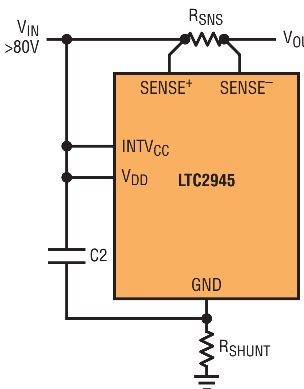


Figure 3a. The LTC2945 deriving power through a high side shunt regulator

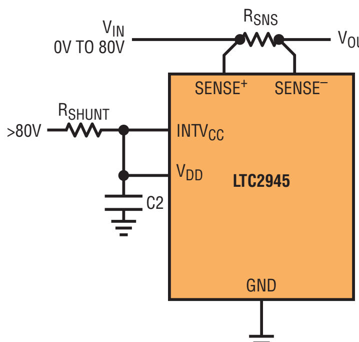


Figure 3b. The LTC2945 deriving power through a low side shunt regulator in a high side current sense topology

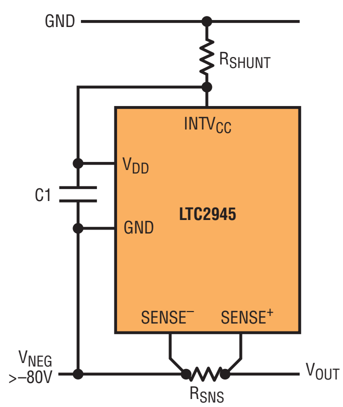


Figure 3c. The LTC2945 deriving power through a low side shunt regulator in a low side current sense topology

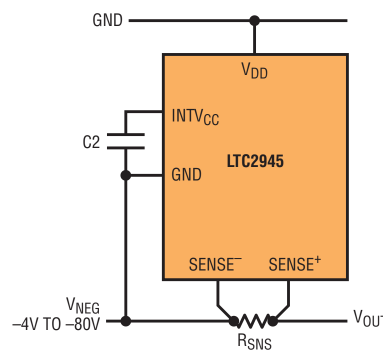


Figure 3d. The LTC2945 deriving power from the monitored supply in a low side current sense topology

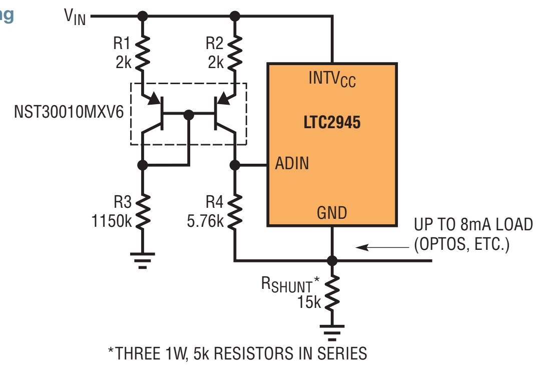
Figure 2a shows a typical LTC2945 application monitoring a 4V to 80V supply and deriving power off the same supply. The bus voltage is measured at the SENSE+ pin through an internal resistive divider and a sense resistor is used to measure the load current on the high side. If the bus voltage to be monitored is below 2.7V, the power for the LTC2945 can be derived from a wide range secondary supply as shown in Figure 2b or a low voltage secondary supply as shown in Figure 2c.

The LTC2945 also integrates a 6.3V, 35mA shunt regulator at the $INTV_{CC}$ pin for operation beyond 80V. Figure 3a shows the LTC2945 used in one such application with its ground floated at 6.3V below the bus voltage. The bulk of the bus voltage is dropped across an external shunt resistor; in practice any current source capable of standing off the bus voltage and supplying LTC2945's operating current will work.

Figure 4 shows how to measure the bus voltage in this configuration using a matched PNP pair and some resistors. The resistor values shown are optimized for V_{IN} of 165V ±10%. The LTC2945's shunt regulator can also be configured as shown in Figure 3b when the only

LTC2945 integrates an oversampling ΔΣ ADC that inherently averages the measured voltage over the conversion cycle to effectively reject noise due to transient spikes and AC power line. Bus voltage, sense voltage and ADIN are measured with total error of less than ±0.75% at full scale over the full industrial temperature range.

Figure 4. Application circuit for measuring the bus voltage in a high side shunt regulator configuration



secondary supply available exceeds 80V in high side current sensing applications.

If the output of the power supply is negative such as in −48V distributed power systems for networking, communications and high end computing equipment, low side current sensing is generally preferred, as shown in Figures 3c and 3d. Figure 3c shows a shunt resistor and LTC2945's shunt regulator limiting $INTV_{CC}$ to 6.3V above a negative supply that exceeds 80V. More commonly, the negative supply is below 80V and instead the internal linear regulator can be used to power the LTC2945 directly, as shown in Figure 3d. In this configuration the V_{DD} pin measures the bus voltage through an internal resistive divider.

Measuring bus voltage in excess of 80V in low side current sensing applications such as Figure 3c can be done by connecting a resistive divider to the ADIN pin as shown in Figure 5.

±0.75% TOTAL ERROR MEASUREMENT ACCURACY

LTC2945 integrates an oversampling ΔΣ ADC that inherently averages the measured voltage over the conversion cycle to effectively reject noise due to transient spikes and AC power line harmonics. Bus voltage, sense voltage and ADIN are measured with total error of less than ±0.75% at full scale over the full industrial temperature range.

The 12-bit ΔΣ ADC provides a full-scale voltage of 102.4mV (25µV/LSB) for sense voltage, 102.4V (25mV/LSB) for bus voltage and 2.048V (0.5mV/LSB) for ADIN. Typical integral linearity error (INL) of the ADIN voltage and the sense voltage are both well within ±0.5LSB, as shown in Figures 6 and 7. The LTC2945 is also ideal in applications where accuracy is important at the low end of the measurements since its specified offset voltages are as low as ±1.1LSB for ADIN and ±3.1LSB for current sense voltage in the worst case.

Figure 5. ADIN senses the bus voltage in low side shunt regulator configuration.

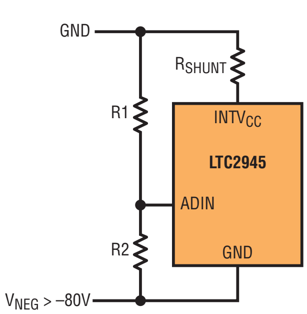


Figure 6. ADIN INL curve

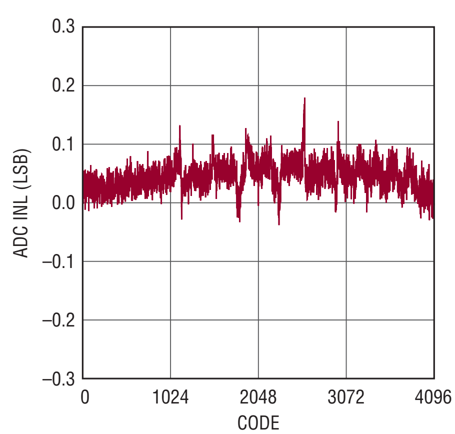
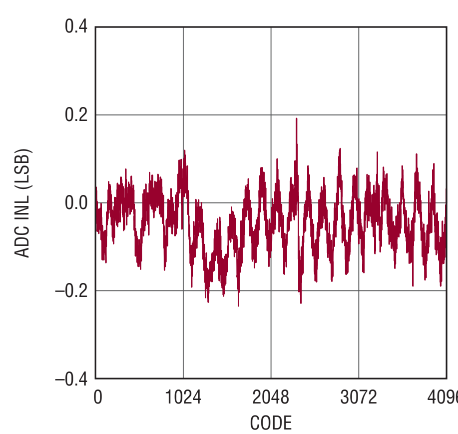


Figure 7. SENSE INL curve



Opto-isolation is common in high voltage systems where the high voltage sections must be galvanically isolated for safety reasons. The LTC2945 accommodates isolated applications by splitting the SDA signal on the I²C interface into an SDAI pin and an SDAO pin (for LTC2945-1, $\overline{\text{SDAO}}$) for applications with an opto-isolator interface.

PEAK VALUES TRACKING AND OVER/UNDERVALUE ALERTS

Keeping track of the minimum and maximum measurement values is important in many power monitoring systems because it could be used to study usage behavior for more efficient resource allocation and is often an indicator of system health. Previously, gathering such information required periodic polling of the power monitor by the system's microprocessor, which wasted precious computation time and potentially tied up the I²C interface. The LTC2945 solves this problem by storing the minimum and maximum values for power, voltage, current, and ADIN. The Page Read feature on the LTC2945 allows these data to be read with just a single I²C read transaction. An $\overline{\text{ALERT}}$ pin can also be configured to signal overvalue or undervalue limit violations for power, voltage, current and ADIN.

UNTRUNCATED 24-BIT POWER DATA

For applications where a digital servo loop is used to regulate the power output of a system, the power data read back from the monitor needs to be monotonic and of high resolution in order to minimize stability issues. The LTC2945 generates 24-bit power data by digitally multiplying the 12-bit sense voltage and 12-bit bus voltage data without truncating the result.

OPTO-ISOLATION AND SHUTDOWN

The LTC2945 can be shut down via the serial I²C interface, reducing the typical quiescent current to 20μA—especially important for battery-powered applications. Opto-isolation is common in high voltage systems where the high voltage sections must be galvanically isolated for safety reasons. The LTC2945 accommodates isolated applications by splitting the SDA signal on the I²C interface into an SDAI pin and an SDAO pin (for LTC2945-1, $\overline{\text{SDAO}}$) for applications with an opto-isolator interface as shown in Figure 8.

For limited amounts of current, the internal linear regulator or shunt regulator can be used to supply the pull-up resistors on the I²C bus. In situations where it is undesirable to tap off the internal regulator and a low voltage supply is not available, the LTC2945-1 allows the pull-up resistors to connect directly to high voltages. The SCL and the SDAI pins are limited to safe voltages by internal 6.3V, 3mA clamps. The SDAO pin is inverted (to $\overline{\text{SDAO}}$) so that it can be clamped by the anode of the input diode of an optoisolator as shown in Figure 9.

SUPPLY TRANSIENTS

The wide operating range of the LTC2945 is advantageous even in applications where the bus voltage is normally well below 80V. Transient voltage surges due to inductive kickbacks in automotive load dump situations and hot swap output shorts are just two possible scenarios where a rugged power monitoring solution is required in order to withstand overvoltage conditions far in excess of the normal operating voltage.

The 100V absolute maximum rating of the LTC2945 makes it easy to guard against these types of voltage surges since there is a wide range of transient surge suppressor (TVS) diodes from which to choose. In certain applications a large

Figure 8. Opto-isolation of a 10kHz I²C interface between the LTC2945 and a microcontroller

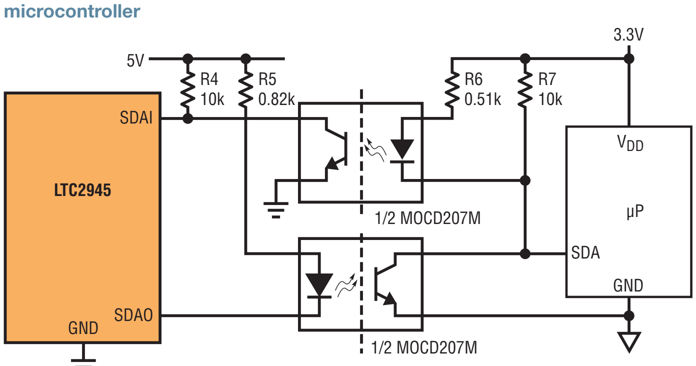
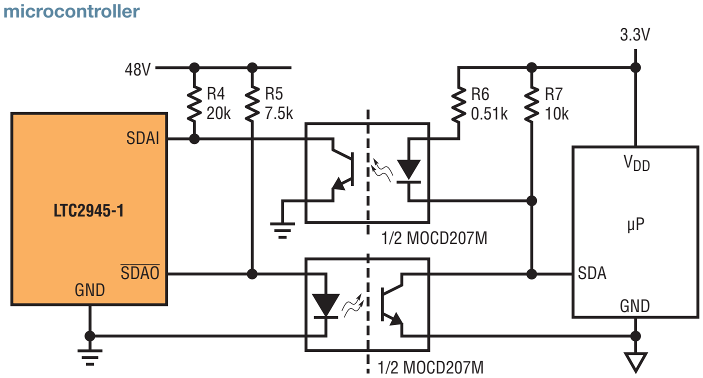


Figure 9 Opto-isolation of a 1.5kHz I²C interface between the LTC2945-1 and a microcontroller



The 100V absolute maximum rating of the LTC2945 makes it easy to guard against voltage surges since there is a wide range of transient surge suppressor (TVS) diodes from which to choose. In certain applications a large MOSFET power device can break down to clip the inductive spike safely, and in most 12V and 24V systems the break-down voltage of these power devices is less than 100V, potentially negating the requirement for a TVS diode.

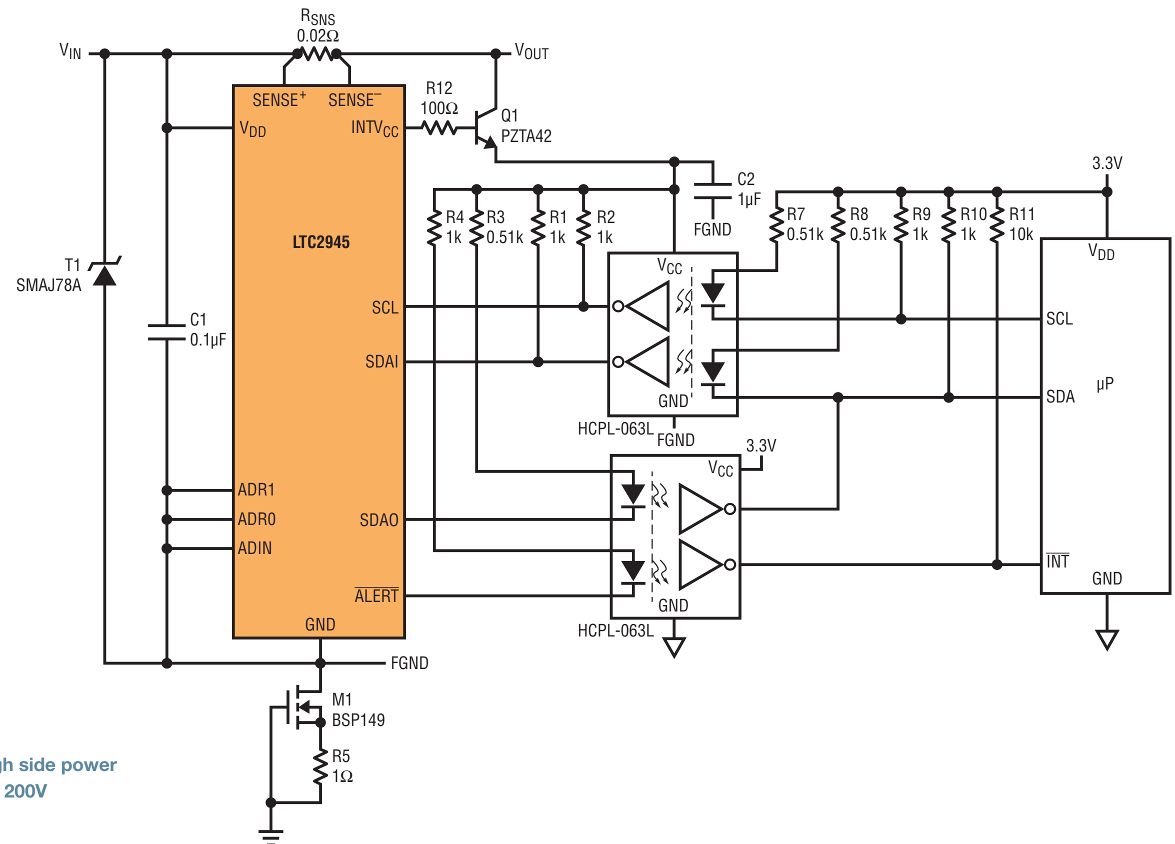


Figure 10. Ruggedized 4V to 80V high side power monitor with surge protection up to 200V

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Hard-clamping the voltage with TVS diode or MOSFET break down may not be practical when the inductive energy is too high or unpredictable. Figure 10 shows a LTC2945-based power monitor that can ride through a 200V surge where its high voltage pins are clamped by T1 to less than 80V. In normal operation, M1 operates in the triode region with the device ground at a few mV above the system ground. During the surge, the device ground is lifted by T1 and the balance of the surge voltage is dropped across M1. The BSP149 has a 200V break down and the surge duration is limited by its safe operating area—for example at room temperature it can survive a 200V surge for 1ms at V_{IN}.

CONCLUSION

The LTC2945 is a highly integrated power monitor that easily fits into a wide range of systems. It offers a 0V to 80V common mode range, 2.7V to 80V operating range, ±0.75% accurate voltage and current measurements, and an on-chip digital multiplier that computes power. Digital watchdog functions such as peak and valley values and window comparators are available for power, voltage, current and an external voltage. Opto-isolation is simplified with a split SDA pin. The LTC2945 is available in space-saving 3mm × 3mm QFN and 12-pin MSOP packages.

Visit www.linear.com/LTC2945 for data sheets, demo boards and other applications information. ■