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#### APPLICATION NOTE 4643

# Achieve ISO 11898-2-Compliant 5V HS-CAN Communication from a 3.3V Supply

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*Abstract: This application note solves a very common problem of powering an automotive electronic control unit (ECU) with only a 3.3V supply. The ISO 11898-2 standard stipulates that only a 5V power supply rail powers the CAN transceiver. This article shows how an automotive CAN transceiver can be supplied with a 3.3V charge pump to provide a low power, low-voltage, and easy solution to this problem. By eliminating the 5V power rail, many automotive OEMs will save weight and cost while improving mileage performance. The article also discusses the circuit's impact on electromagnetic emissions (EME) and immunity (EMI) and electromagnetic compatibility (EMC). The MAX13041 CAN transceiver is combined with the MAX1759 charge pump in the application.*

A similar article appeared in the July/August 2010 issue of *Power Systems Design*.

## Introduction

From the first introduction of an automobile, manufacturers witnessed a rising demand for more comfort, efficiency, environmental cleanliness, better performance, and safer vehicles. With each improvement, the amount of wiring needed in vehicles began to increase significantly. After its invention by Bosch in the early 1980s, the CAN-bus network was quickly adopted by the auto industry because it reduced the weight and cost of a wiring harness.

Older centralized control systems had all actuators and switches through multiple wires. The newer CAN-bus system is a distributed system with electronic control units (ECUs) located at the place where each is needed and connected through a two-wire bus system. This new system brought significant advantages and addressed manufacturers' performance and cost goals, but it needed to be standardized to allow proper communication among different suppliers' ECUs.

This standardization was first done in 1993 by the ISO (International Organization for Standardization) organization. In 2003 a revision of the standard followed. Since then the ISO 11898 standard is the de facto standard for all CAN communication in a vehicle; it is universally accepted by all OEMs.

To be compliant with the ISO 11898-2:2003 standard, the CAN transceiver bus driver usually needs to be supplied by a 5V supply rail to provide the proper bus signaling levels. This specification is clear, but implementing it is not always so straightforward. Most electronic systems engineers are familiar with the problem when the subsystem's power requirements are not met by the main supply rails. In these cases the available power rails often cannot directly supply a CAN transceiver. Simply put, there is only a single 3.3V

supply available, often because lack of space prevents inclusion of the optimal number of supplies. In other cases, generating the 5V directly from the battery rail might not be acceptable because of heat dissipation issues. This is especially true in systems that need CAN communication at high battery voltages, e.g., during a double-battery condition in a vehicle or in a 24V truck system.

There is a way to achieve a 5V supply from 3.3V designs. Voltage converters can generate the desired voltage levels and charge pumps are often the best choice for applications requiring a combination of low power, simplicity, and low cost. Charge pumps are, moreover, easy to use because they do not require expensive inductors or additional discrete components.

## Selecting the Charge Pump

### Transceiver Supplies

The  $V_{CC}$  pin on the [MAX13041](#) CAN transceiver is used to supply the ICs internal voltage reference and receiver stage and to provide the proper communication levels on the bus. To be compliant with the ISO 11898-2 standard,  $V_{CC}$  must be between 4.75V and 5.25V (normal operating-voltage range).

The  $V_{I/O}$  input provides an interface with 3.3V I/O microcontrollers to get the correct voltage level between the controller's and transceiver's receive/transmit stage (RXD/TXD). This pin can also be supplied by 5V, of course, when the application is communicating with such a controller.

The  $V_{BAT}$  pin, which is usually connected to the car battery (12V), supplies a very-low-quiescent wake-up detection circuit. This pin enables the MAX13041 to wake up from sleep mode on a CAN message, and it puts the transceiver in a low-power mode if an undervoltage on the  $V_{BAT}$  supply is detected.

For a detailed description of all other pins, please refer to the MAX13041 data sheet.

### Supply Currents

The CAN bus can have one of two logical states: recessive or dominant (**Figure 1**). In normal communication mode, the MAX13041 needs a maximum  $V_{CC}$  input current of 80mA in the dominant state and 10mA in the recessive state. The currents into  $V_{I/O}$  and  $V_{BAT}$  may be ignored. During a bus failure, however, the  $V_{CC}$  supply current can increase significantly, especially if the CAN\_H bus line is shorted to ground. The transceiver will limit the short-circuit current to  $I_{O(SC)} = 95mA$ . To avoid risking a breakdown of the supply voltage, it is better to dimension the charge-pump output current for this case.

Taking the above into consideration, supplying the CAN transceiver with the proper power requires a charge pump with an output voltage of 5V, the voltage tolerance mentioned above, and a minimum output current capability of 95mA.

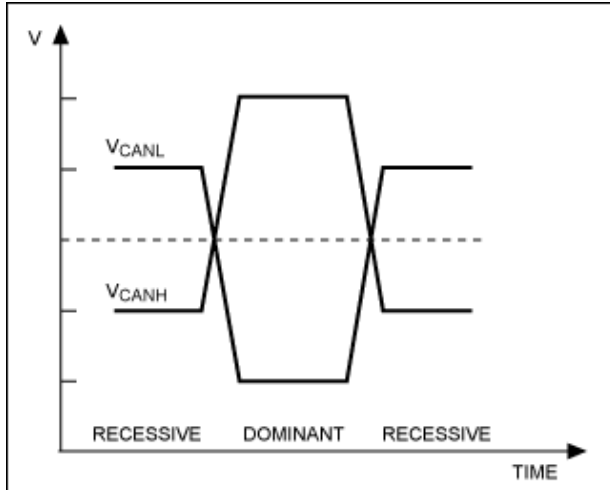


Figure 1. Voltage level of the CAN bus for logic states recessive and dominant.

## Charge Pump

Although many conventional charge-pump devices are on the market, this application note focuses on the [MAX1759](#) buck/boost regulating charge pump to solve the power-rail issue.

The MAX1759 delivers a regulated 5V output voltage from an input voltage of 1.6V to 5.5V. Its switching frequency is 1.5MHz, allowing the use of small external capacitors at 100mA output current. The device's architecture allows the input voltage to be higher or lower than the regulated output voltage. However, in this application it operates as step-up voltage converter only. When  $V_{IN}$  is lower than  $V_{OUT}$ , the charge pump operates as a regulated step-up voltage doubler. When lightly loaded, the charge pump switches only as necessary to supply the load, resulting in low quiescent current. Output voltage ripple does not increase with light loads.

For a detailed description of all the charge pump's features, please refer to the MAX1759 data sheet.

## Example 3.3V Circuit with the MAX13041 and MAX1759

The circuit in **Figure 2** illustrates how easy it is to supply the MAX13041 from the output of the MAX1759 charge pump. The MAX1759 is simply added to the  $V_{CC}$  input of the CAN transceiver (the blue dashed line), producing a 5V output voltage with the required tolerance and output current. This configuration allows the rest of the circuitry to be supplied by lower voltages. In this example, an external supply voltage of 3.3V (green) is chosen to supply the charge pump (IN), the microcontroller, and the  $V_{I/O}$  level translator voltage of the transceiver. The active-low SHDN input of the charge pump is pulled high, putting the part into an "on" state. The detailed dimensioning of the input/output ( $C_{IN}$ ,  $C_{OUT}$ ) and the flying capacitor ( $C_X$ ) is described in the MAX1759 data sheet.

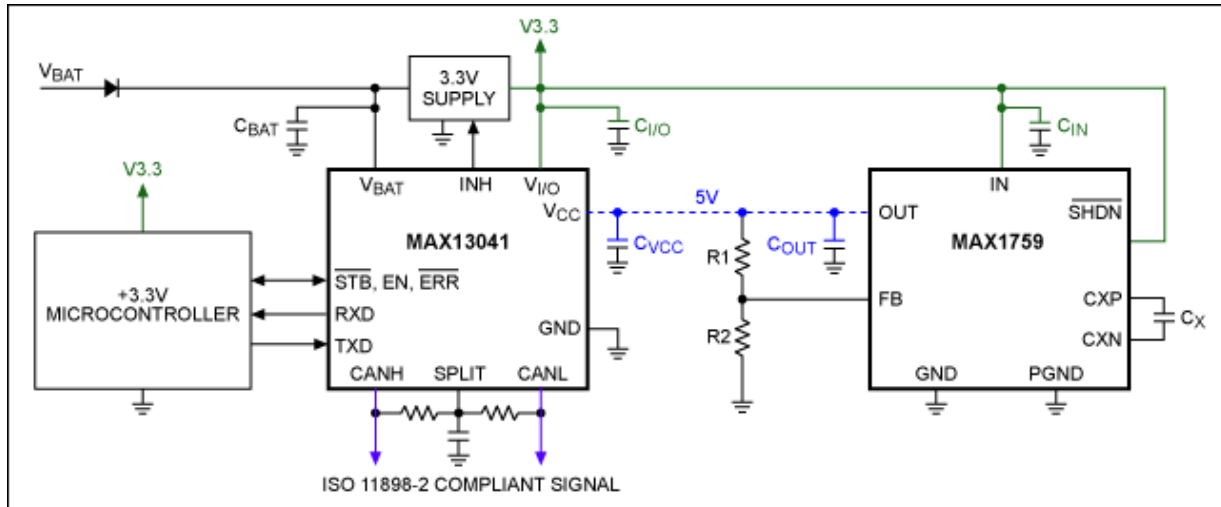


Figure 2. A circuit for supplying 5V to the MAX13041 CAN transceiver uses the MAX1759 charge pump.

## Electromagnetic Compatibility

Achieving electromagnetic compatibility (EMC) can be a challenge in CAN applications, especially if systems are supplied with a switching voltage regulator. The wiring harness of the CAN system is particularly problematic, as the CAN\_H and CAN\_L pins of the CAN transceiver are the interface to the bus network running into the entire vehicle. If care is not taken, one can encounter, or create, interference that propagates from the CAN supply, through the transceiver, over the bus wires, and into the neighboring cables of the wiring harness. This interference can cause miscommunication or malfunctioning of the transmitting control unit or other control units in the system.

Because of this concern, Maxim tested the EMC behavior of the MAX13041 when it is supplied by the MAX1759 charge pump. Maxim considered two domains: electromagnetic immunity (EMI) and electromagnetic emission (EME). Test results were compared with the behavior of the standard 5V-supplied MAX13041. These tests determine the impact of the charge pump in terms of EMC interference and demonstrate the charge pump's robustness against interference coming from the CAN lines propagating to the supply.

## Immunity Testing

The ISO 11452 specifications describe several methodologies for testing immunity to RF disturbances, including bulk current injection (BCI), transversal electromagnetic-cell (TEM-cell), stripline, and direct power injection (DPI).

Maxim uses the DPI method because it is highly reproducible (due to the use of a well-defined test board) and requires relatively little test effort. The DPI test injects a certain AC voltage into the bus lines, modulated or not, and checks the integrity of the transmitted data signal through the RXD pin of the transceiver. This method facilitates comparison among different suppliers' designs and, moreover, is used by independent laboratories testing CAN transceivers (e.g., the IBEE *Ingenieur Buero fuer industrielle Elektronik*).

## Test Setup

The test setup (Figure 3) consists of three identical transceivers mounted on a defined PCB, with one of them supplied by the MAX1759 charge pump. Node 1 operates as a transmitter for a bit pattern that simulates a CAN message to be received and monitored at the RXD output ports of all transceivers. For RF decoupling of outputs Rx1 to Rx3 as well as the input TxD1, 1kΩ resistors are used. A buffer ceramic capacitor ( $C = 100\text{nF}$ ) is used at the supply ports,  $V_{CC}$  and  $V_{BAT}$ , of every transceiver IC. The resistors at the wake-up pin have a value of 33kΩ. The devices are set to normal mode by tying both the EN and active-low STB pins high. The

$V_{CC}$  voltage for node 1 is generated by the MAX1759 charge-pump circuit, which is supplied with 3.3V. The 3.3V supply was also used as the  $V_{I/O}$  voltage of transceiver node 1.

The output capacitor C1 for the charge pump is 10 $\mu$ F, the flying capacitor C2 is 330nF, and the IN pin is decoupled with a 10 $\mu$ F capacitor. In the test circuit, the bus termination is realized by a central termination using the 60 $\Omega$  R4 resistor. Symmetrical RF coupling/decoupling is realized with the parallel RC combination R5/R6 = 120 $\Omega$ , C3/C4 = 4.7nF. The external 3.3V, 5V, and 12V supplies are provided by standard power supplies, filtered by a filtering network.

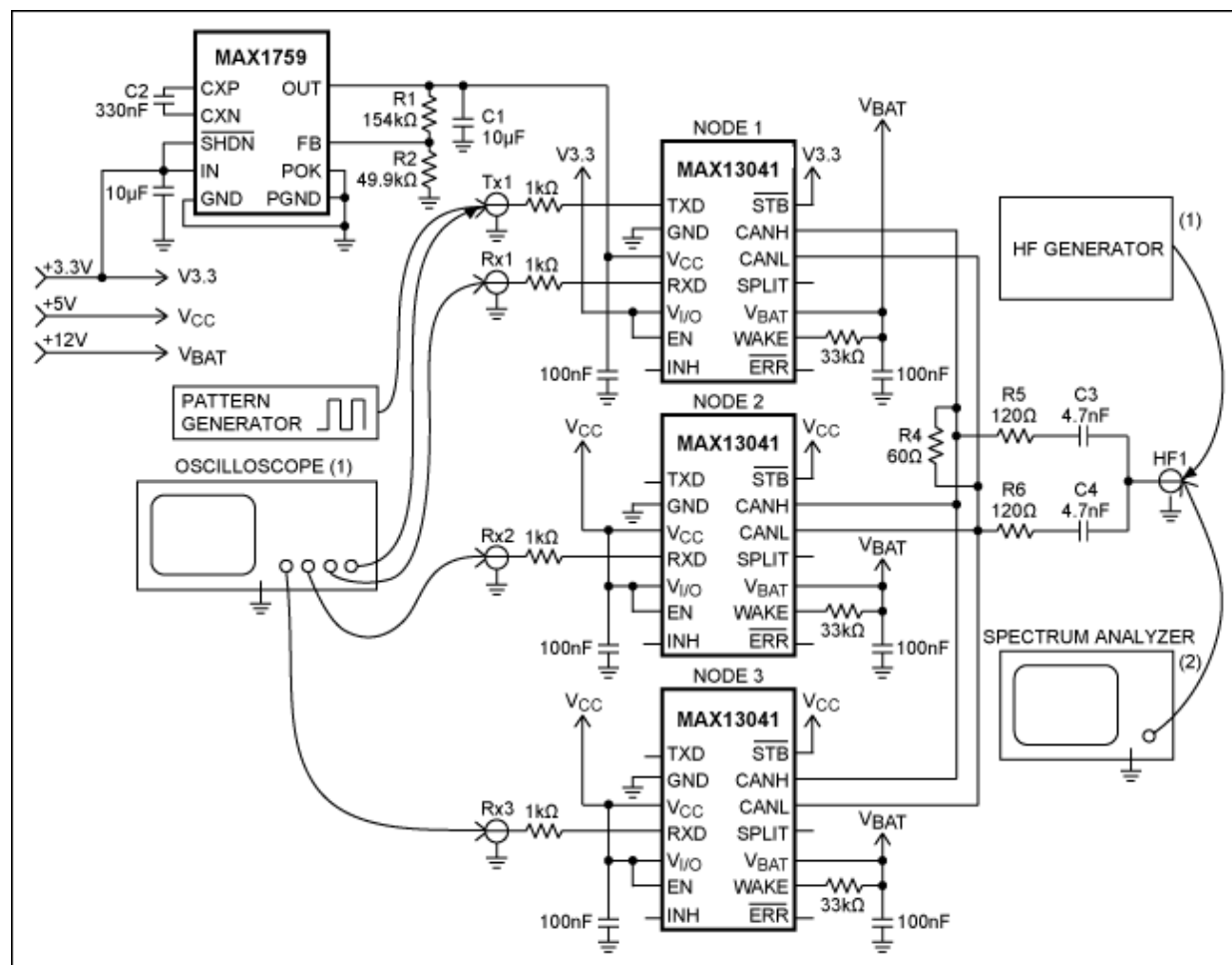


Figure 3. Test setup for DPI and emissions testing.

## Test Procedure

The test was performed with the MAX13041 CAN transceivers operating in normal mode. The first test run was performed with all transceivers supplied by a standard  $V_{CC} = 5V$  supply. A pattern generator produced a square wave with a duty cycle of 50% to simulate a CAN signal (with permanent data alternation 0-1-0) of 500kbps on the TXD pin of node 1. An HF generator on the RF input (HF1) injected an amplitude-modulated (AM) AC voltage with a certain frequency at a power of 36dBm into the CAN lines to simulate interference.

To evaluate immunity, the Rx signals of the three transceivers in the network were compared under the influence of the interference to the signal fed into TXD using an oscilloscope.

A validation mask with a maximum allowed voltage deviation of  $\pm 0.9V$  and a maximum allowed time deviation

of  $\pm 0.2\mu\text{s}$  was overlaid across the TXD signal-wave shape.

If the failure criteria is true (i.e., if one of the transceivers' RXD signals is beyond the validation mask window), the injected RF power is reduced by 0.2dBm and the same test (at the particular frequency step) is repeated until the failure criteria are false. Then, the current power value was recorded and the next frequency step adjusted. The test was carried out over a 10MHz to 100MHz frequency range.

## DPI Test Results

**Figure 4** shows the test result curves of the MAX13041 supplied by a standard 5V supply on  $V_{CC}$  (blue) and supplied by the charge pump (pink). The X axis indicates the frequency range, while the Y axis indicates the maximum power injected without failure. As the blue and the pink lines are almost identical, it can be seen that the EMI behavior of the circuit is dominated by the CAN transceiver's EMI susceptibility, rather than that of the charge pump. Therefore, supplying the MAX13041 CAN transceiver with the MAX1759 charge pump does not significantly influence the EMI behavior of the circuit.

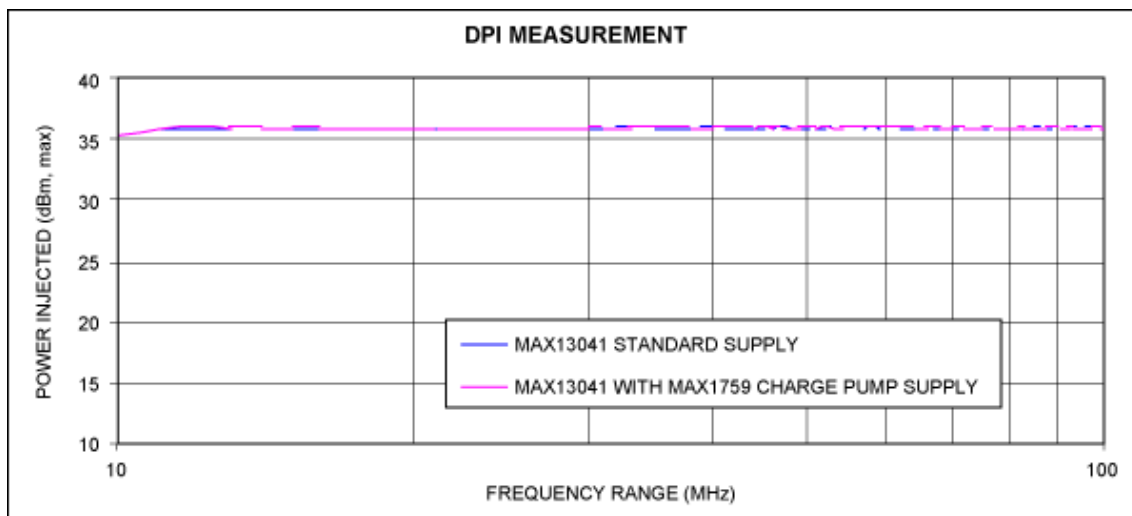


Figure 4. DPI test results.

## Emissions Testing

The emissions test was performed on the same test board and test setup as the DPI test, except that the power injector (HF generator) was replaced by a spectrum analyzer. The test was again performed with the CAN transceivers operating in normal mode. The first test was performed with all transceivers supplied by a standard  $V_{CC} = 5\text{V}$  supply. The applied square wave on the CAN TXD input (simulating a transmitting bit stream of 500kbps) was maintained; the emissions on the CAN lines measured and recorded by the spectrum analyzer in the frequency range from 100kHz to 1GHz. The DSO is not required (Figure 3).

## Emissions Test Results

**Figure 5** shows the resulting EME curves of the MAX13041 supplied by a standard 5V supply on  $V_{CC}$  (blue), and by the MAX1759 charge pump (pink). The X axis indicates the frequency range, while the Y axis indicates the level of the disturbances.

Again, the blue and the pink lines (one transceiver supplied by the charge pump) are almost identical to the lines for the MAX13041 with a standard 5V supply (blue). It can, therefore, be seen that the emissions behavior of the circuit is dominated by the CAN transceiver's emissions compatibility, rather than the charge pump's. These test results indicate that a CAN transceiver can be supplied with a charge pump without significantly influencing the overall EMC behavior of the system.

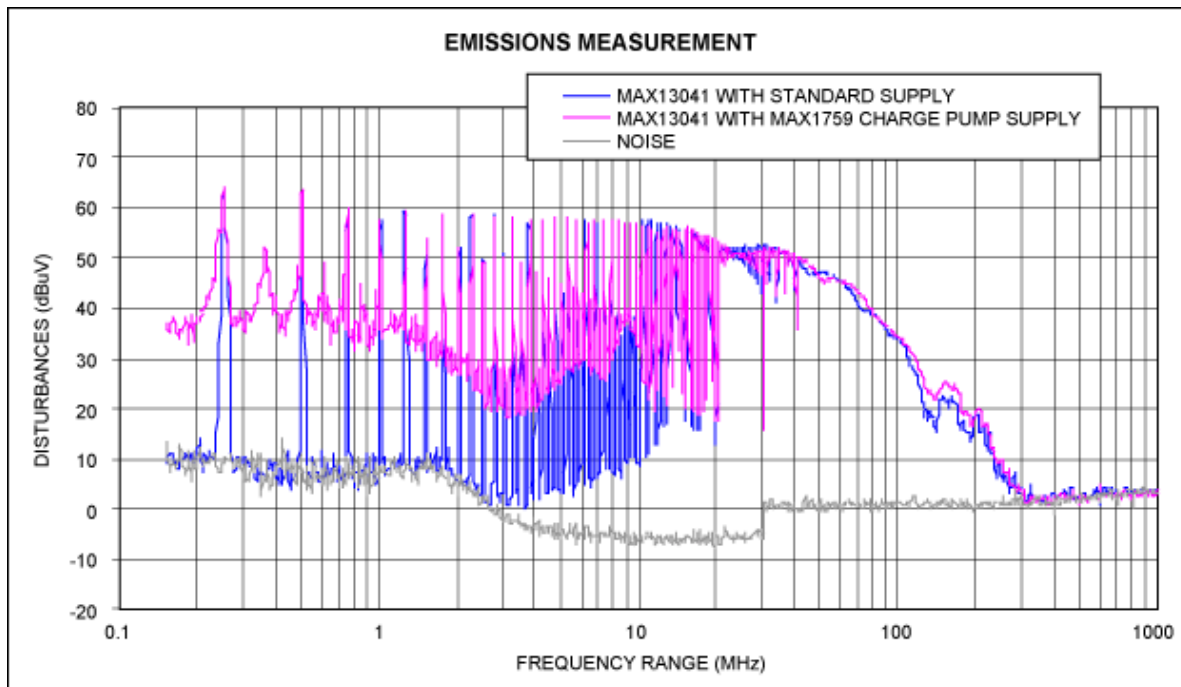


Figure 5. EME curves of the MAX13041 supplied by a standard 5V (blue) and by the MAX1759 charge pump (pink).

## Conclusion

It can be challenging to achieve EMC in CAN applications, especially if they are supplied by switching voltage regulators (charge pumps). However, this application note demonstrates that the EMC behavior of the circuit is governed by the CAN transceiver's EMC, rather than that of the charge pump.

Given the above understanding, the MAX13041 can be supplied with the 3.3V MAX1759 charge pump. Applications that require 3.3V low-power, low-voltage operation and low cost can use this option when a 5V power-supply rail is not readily available.

### Related Parts

<a href="#">MAX13041</a>	$\pm 80\text{V}$ Fault-Protected High-Speed CAN Transceiver with Low-Power Management and Wake-On CAN	<a href="#">Free Samples</a>
<a href="#">MAX1759</a>	Buck/Boost Regulating Charge Pump in $\mu\text{MAX}$	<a href="#">Free Samples</a>

### More Information

For Technical Support: <http://www.maximintegrated.com/support>

For Samples: <http://www.maximintegrated.com/samples>

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Application Note 4643: <http://www.maximintegrated.com/an4643>

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