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Integrated Power Supply Solution for Vehicle Tracking System

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INTRODUCTION

A vehicle tracking system (VTS) is typically installed in cars and trucks. A VTS provides real-time information about the speed, location, and direction of the vehicle using technology, such as a global positioning system (GPS).

For a VTS to work reliably, it needs to have a robust dc-to-dc power supply. A power supply must be designed to protect the system from common automotive fault conditions like load dump, cold crank, reverse polarity, and other potential destructive transients described in the ISO 7637-2 and ISO 16750-2 standards. In addition, in the absence of power coming from the vehicle, the system must be able to switch to the backup battery to ensure continuous operation. Ultimately, an automotive power supply must comply with automotive electromagnetic interference (EMI) standards, specifically CISPR 25.

To address these challenges, Analog Devices, Inc., developed the EVAL-ADVTS4152-EBZ power supply solution, which is a high performance, simplified power supply solution for vehicle tracking systems.

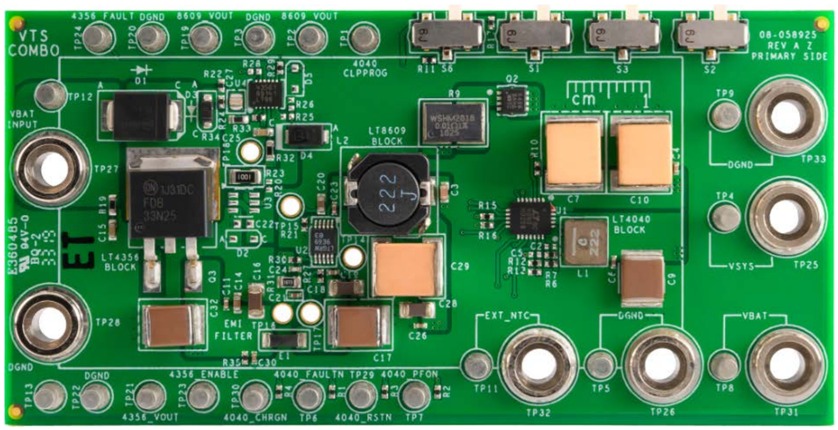

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Figure 1. EVAL-ADVTS4152-EBZ Power Supply Solution Evaluation Board

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REVISION HISTORY

10/2020—Revision 0: Initial Version

INTEGRATION SOLUTION

The EVAL-ADVTS4152-EBZ power supply solution integrates three main blocks: the LT4356-1 surge stopper, the efficient LT8609A step-down regulator, and the LTC4040 battery backup power manager. These three blocks work together to provide reliable and efficient power to downstream electronics like a VTS.

The EVAL-ADVTS4152-EBZ is compatible with a nominal 12 V or 24 V system and designed to output 5 V and deliver 3 A of continuous current. When the power from a car battery is not available, the system automatically switches to a backup supply from a single cell Lithium Ion (Li-Ion) or Lithium Iron Phosphate ($LiFePO_4$) battery.

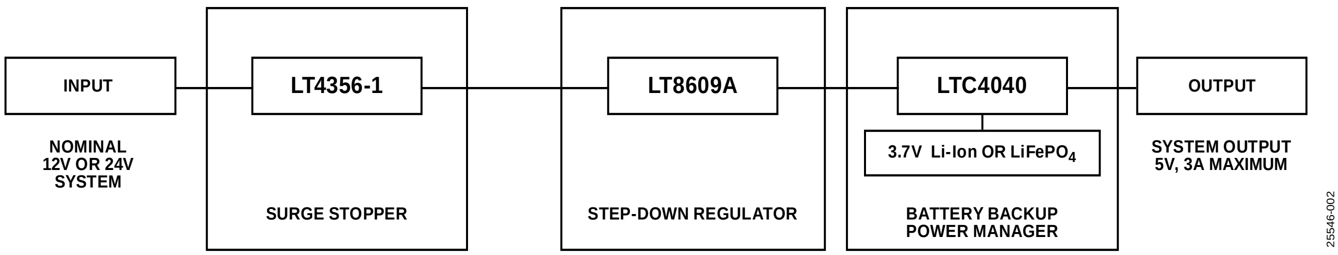

Figure 2. EVAL-ADVTS4152-EBZ Functional Block Diagram

Table 1. EVAL-ADVTS4152-EBZ Electrical Specification

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
INPUT					
Operating Range	Suited for 12 V and 24 V power system				
	Main	6.5	12 or 24	38	V
	Battery	2.7		5	V
Positive Surge Protection				200	V
Reverse Protection		−40			V
OUTPUT					
Voltage		4.5		5.5	V
Ripple	Output = 5 V, 2 A				
	Main 12 V (buck mode)		3.842		mV
	Battery 3.6 V (boost mode)		9.522		mV
Current				3	A
BACKUP BATTERY					
Operating Range		2.7		5	V
Selectable Charging Voltage	Li-Ion		3.95, 4.0, 4.05, or 4.1		V
	$LiFePO_4$		3.45, 3.5, 3.55, or 3.6		V

SURGE STOPPER

Designing an automotive power supply to handle high voltage transients can be challenging because this requires a device to dissipate excess power while leaving sensitive electronics undamaged. The EVAL-ADVTS4152-EBZ power supply solution features the LT4356-1 surge stopper that protects the system from high voltage transients and continues to operate during events like these.

The LT4356-1 drives an external N-channel, metal-oxide semiconductor field effect transistor (MOSFET) as a pass transistor (see Figure 3). In normal operation, the LT4356-1 fully turns on the MOSFET and provides a low impedance path from the input to the downstream load. If the input voltage surges too high, the LT4356-1 controls the gate of the MOSFET and regulates the output to a safe voltage level set by the R33 and R34 resistive divider from the OUT pin to ground. The MOSFET stays on until the capacitor charge (C_{TMR}) connected at the TMR pin to ground reaches 1.35 V. At that point, the GATE pin pulls low turning the MOSFET off.

Load Dump

A load dump is an example of the high voltage transients. A load dump happens when the alternator disconnects from a car battery while being charged causing a voltage surge. The EVAL-ADVTS4152-EBZ uses an LT4356-1 surge stopper to protect sensitive automotive electronics from this kind of transient condition.

Test Setup

A load dump test pulse was generated using a DC1950A load dump generator and sent across the inputs of the EVAL-ADVTS4152-EBZ. A 1 A constant current load is then applied across the output of the EVAL-ADVTS4152-EBZ. Figure 4 shows the test setup for a load dump condition.

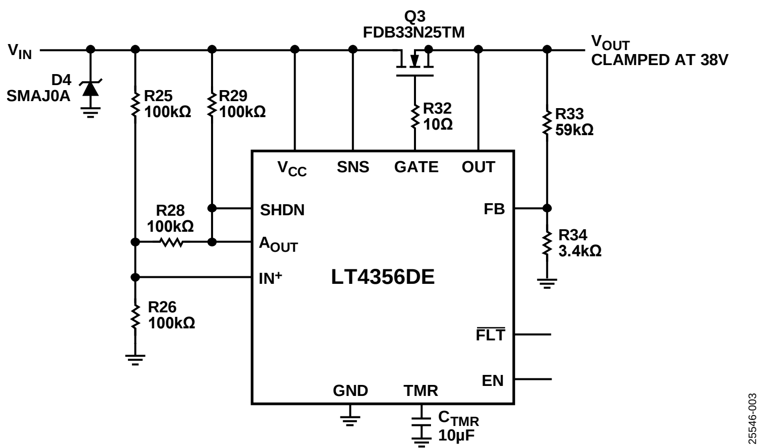

Figure 3. LT4356-1 Surge Stopper

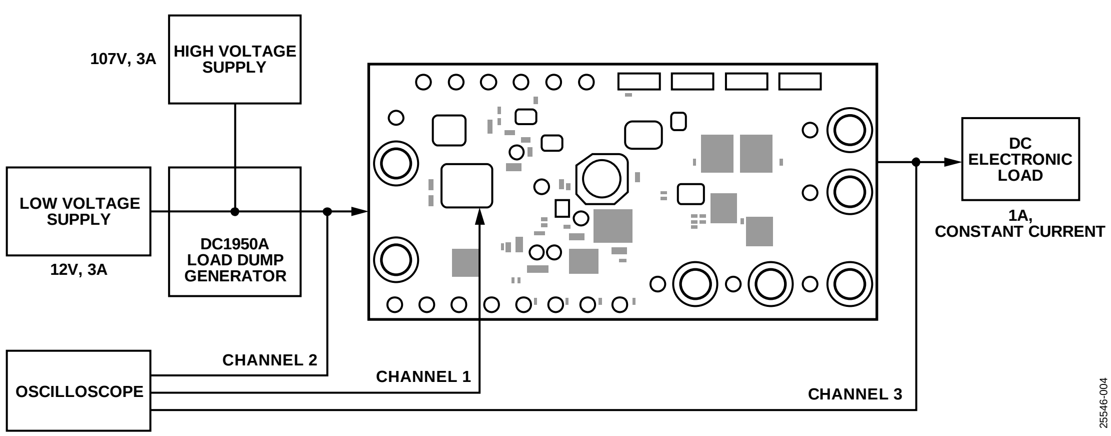

Figure 4. Test Setup for a Load Dump Condition

The actual surge waveform, shown in Figure 5, displays in Channel 2 (C2) and reads a 105.6 V surge that decays around 400 ms. The voltage reading across the output is kept at 5 V and is shown in Channel 3 (C3), indicating that the power was not interrupted. In Figure 5, the LT4356-1 response is also shown in Channel 1 (C1). The flat region in the waveform shows that the chip is regulating the voltage at the desired 38 V clamp voltage (see Figure 5).

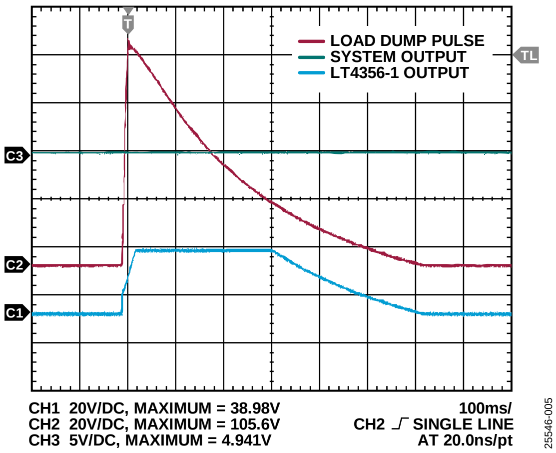

Figure 5. EVAL-ADVTS4152-EBZ Response During a High Transient Voltage

STEP-DOWN REGULATOR

The output of the LT4356-1 is then connected to the input of the LT8609A high efficiency, step-down regulator (see Figure 6). The LT8609A has a wide input range from 3.0 V to 42 V. A resistor tied between RT and ground is used to set the switching frequency. A SYNC pin allows users to enable the spread spectrum modulation for low EMI operation.

BATTERY BACKUP POWER MANAGER

For the VTS to function continuously, it must have a backup power supply in the absence of power from a car battery. The EVAL-ADVTS4152-EBZ has a LTC4040 high current, step-up, dc-to-dc regulator that backs up the supply from a single cell, Li-Ion or $LiFePO_4$ battery (see Figure 7).

When the output of the LT4356-1 drops below the 1.2 V power fail input (PFI) threshold, the 2.5 A boost regulator delivers power from the backup battery to the downstream load.

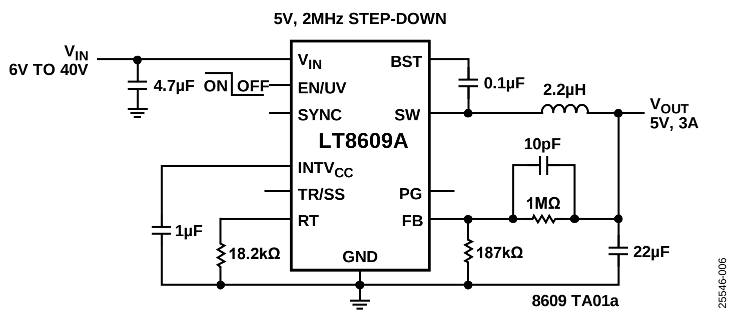

Figure 6. LT8609A Step-Down Regulator

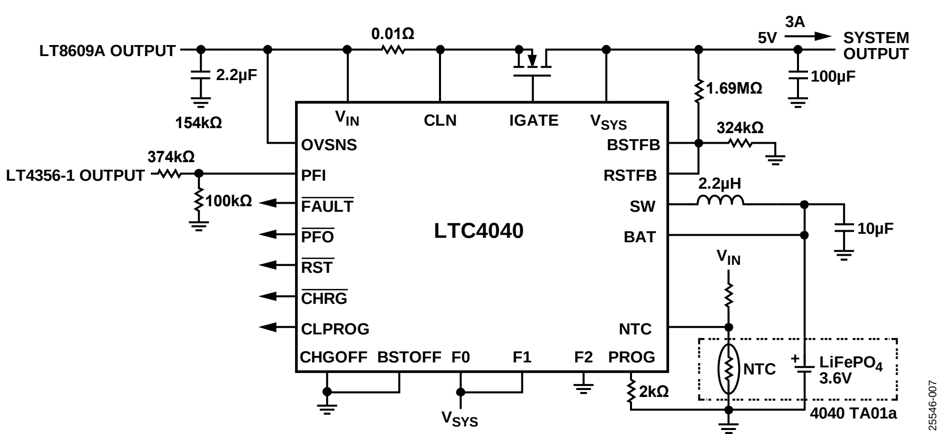

Figure 7. LTC4040 Battery Backup Power Manager

Normal to Backup Battery Mode

To simulate brownout conditions, the power supply across the input of the EVAL-ADVTS4152-EBZ was disconnected to see the transitioning waveform from normal operation to backup battery mode. Figure 9 shows the test setup. This simulation also shows how the EVAL-ADVTS4152-EBZ continues to operate during undervoltage transients such as cold crank.

In Figure 8, a nominal 12 V input is displayed in Channel 1 (C1). The system output displayed in Channel 3 (C3) shows that the 5 V output was uninterrupted as the 12 V input drops. This result also shows that the EVAL-ADVTS4152-EBZ can continuously operate even during cold crank transients.

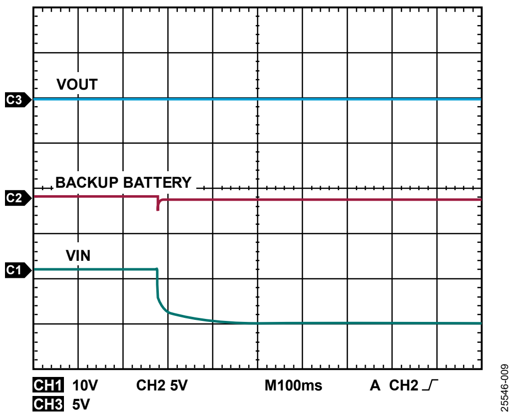

Figure 8. EVAL-ADVTS4152-EBZ Response During Brownout Conditions (VIN = 12 V and VOUT = 5 V)

Choosing A Charge Voltage for the Battery

When car battery power is available, the step-up regulator operates in reverse as a step-down battery charger. The charging voltage can be configured according to the battery type via a user-selectable pin. The LTC4040 offers four different charge voltage options for each of the two battery chemistries (Li-Ion and $LiFePO_4$), and these options are selected through the S1, S2, and S3 slide switch inputs. Table 2 shows the switch configurations for choosing a charge voltage for the two types of batteries.

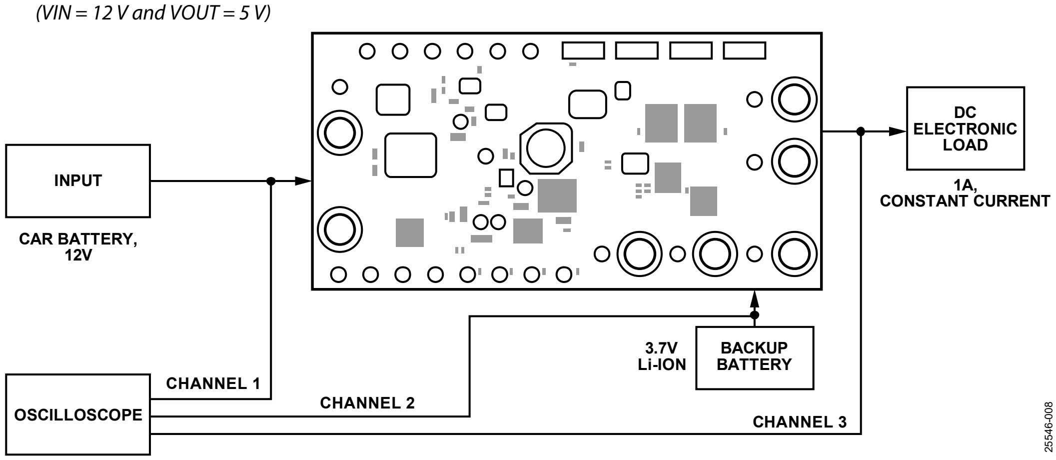

Figure 9. Brownout Conditions Simulation Test Setup

Table 2. Charge Voltage Setting for the Backup Battery

Battery Type	Switch Setting	Min	Typ	Max	Unit
BATTERY REGULATED OUTPUT VOLTAGE					
For $LiFePO_4$ Option	S1 = 0, S2 = 0, S3 = 0	3.42	3.45	3.48	V
	S1 = 0, S2 = 1, S3 = 0	3.47	3.50	3.53	V
	S1 = 0, S2 = 0, S3 = 1	3.52	3.55	3.58	V
	S1 = 0, S2 = 1, S3 = 1	3.57	3.60	3.63	V
For Li-Ion Option	S1 = 1, S2 = 0, S3 = 0	3.92	3.95	3.98	V
	S1 = 1, S2 = 1, S3 = 0	3.97	4.00	4.03	V
	S1 = 1, S2 = 0, S3 = 1	4.02	4.05	4.08	V
	S1 = 1, S2 = 1, S3 = 1	4.07	4.10	4.13	V

THERMAL SHUTDOWN PROVISION

The EVAL-ADVTS4152-EBZ has an optional ADT6401 pin-selectable temperature switch for over temperature protection if the design needs to protect from abnormally high dc voltage. For reference, see the EVAL-ADVTS4152-EBZ, UG-1916 for the ADT6401 schematic.

PRECOMPLIANCE TESTING

ISO 7637-2:2011 AND ISO 16750-2:2012 STANDARDS

The ISO 7637-2:2011 and ISO 16750-2:2012 standards describe the possible transients and specify the test methods to simulate the transients. The test requirements required to comply are shown in Figure 10 as a reference.

Clause	Test Requirement
ISO 7637-2:2011	
ISO 16750-2:2012	
4.2	Direct Current Supply Voltage
4.3	Overvoltage
4.4	Superimposed Alternating Voltage
4.5	Discontinuities in Supply Voltage
4.6	Momentary Drop in Supply Voltage
4.6.1	Reset Behavior at Voltage Drop
4.6.2	Starting Profile
4.6.3	Load Dump – Test A and Test B
4.7.2.3	Reversed Voltage – Case 2
4.9	Open Circuit Tests
4.9.1	Single Line Interruption
4.9.2	Multiple Line Interruption
4.10.2	Short Circuit Protection – Signal Circuits

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Figure 10. ISO 7637-2 and ISO 16750-2 Test Requirements

CISPR 25 RADIATED AND CONDUCTED EMISSION

CISPR 25 is an automotive standard that regulates radiated and conducted emissions for the protection of on-board receivers in a vehicle. The radiated EMI performance of EVAL-ADVTS4152-EBZ is shown in Figure 11 and Figure 12. While the conducted EMI performance is shown in Figure 13 and Figure 14. The red lines in Figure 11 through Figure 14 represent the CISPR25 Class 5 radiated and conducted emission peak limits.

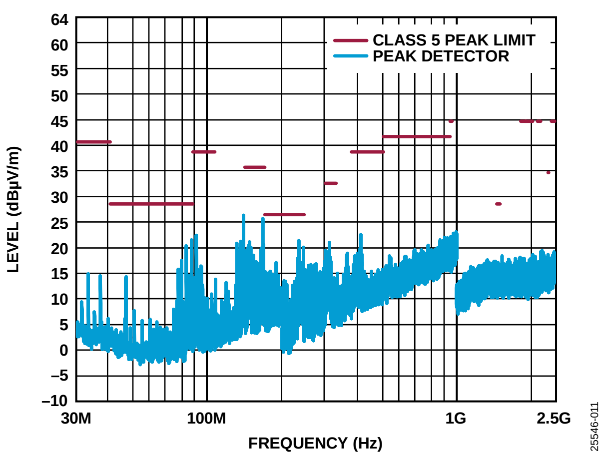

Figure 11. Radiated EMI Performance, Horizontal Polarization

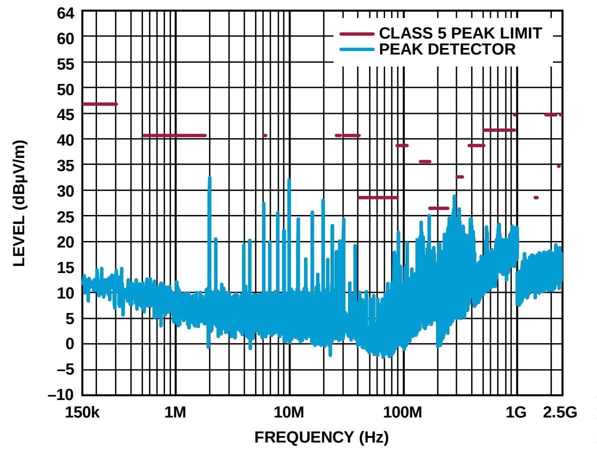

Figure 12. Radiated EMI Performance, Vertical Polarization

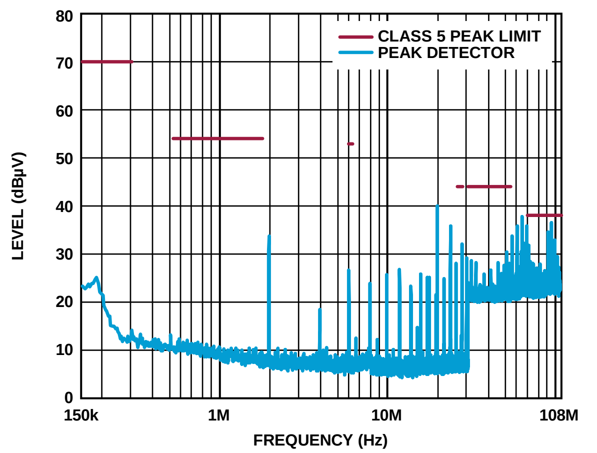

Figure 13. Conducted EMI Performance, Positive Polarity

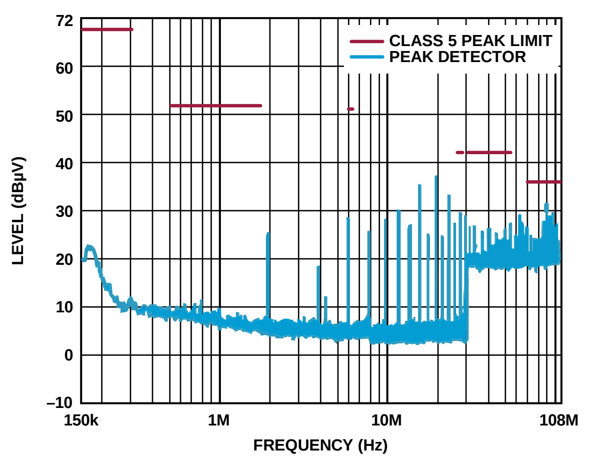

Figure 14. Conducted EMI Performance, Negative Polarity

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