Keysight Technologies

Testing Automotive DC-DC converter with Keysight TS-8989

Application Note

Unlocking Measurement Insights

A start-stop system of automobiles automatically shuts off engine combustion during standstill, and restarts the engine immediately when the driver engages the accelerator. This system is advantageous to vehicles running in a city with frequent stops at traffic lights, or during traffic congestion. The numbers of vehicles equipped with start-stop systems are growing these days, driven by efforts to reduce fuel consumption and carbon emissions.

As the engine startup process draws high amounts of current, typical voltage levels of 12 V supplies to electronic boards may dip to as low as 6 V, half of the vehicle battery supply. This will impair the operation of electronic devices, in the form of interruption of radio or navigation reception, fan ventilation cut-off etc. A high-power DC-DC converter electronic control unit (ECU) is designed to prevent phenomena that may cause any discomfort to both driver and passengers during operation of start-stop system, by stabilizing the 12 V electrical supply to electronic devices.

Functional testing of a DC-DC converter generally requires a combination of emulation, simulation and measurement: emulation of power input; load simulation of electronic devices; measurement of power efficiency and stability of the ECU etc. Keysight has a family of off-the-shelf test instrumentation designed for testing automotive DC-DC converters. They are easily configured and accelerate your test development time.

Operation of DC-DC Converter

Figure 1 is a simplified block diagram that illustrates the operation of a typical DC-DC converter ECU. During normal operation mode – driving or standstill condition, the ECU will not be activated; battery input is bypassed to the network of the electronic board directly.

Whenever there is an engine startup, a crank signal is sent to trigger the ECU, entering boost mode. Bypass relay is opened and the ECU with step up transformer is activated. When the battery voltage decreases to a level lower than 12 V due to start of impulse, the ECU will boost a constant voltage of around 12 V to the output. When the battery supply is back to the nominal voltage level at around 12 V, the ECU will then been deactivated and the bypass relay is closed, returning to normal operation mode.

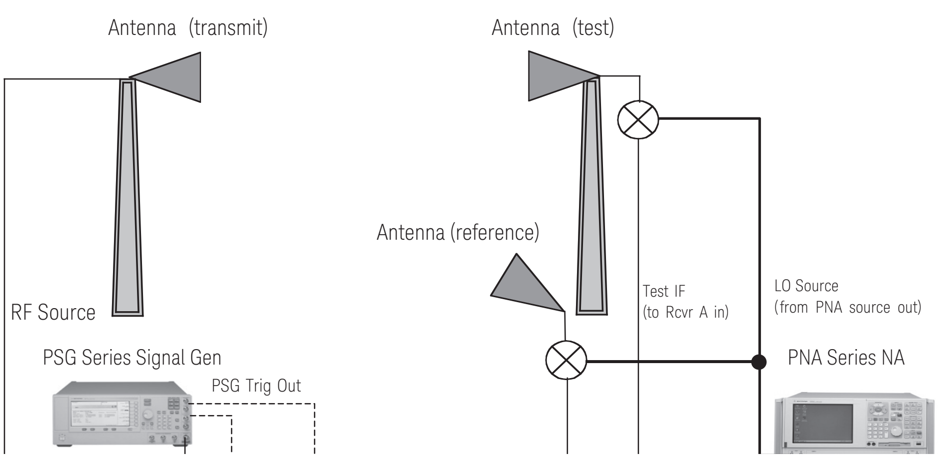

Figure 1: Block Diagram of DC-DC converter

Emulating Input Signals

Under normal operation testing, the input signal is a high-power static input for power efficiency measurement purposes. The input source may go as high as 30-40 A to supply electronic network within a vehicle.

During boost mode, it is necessary to emulate battery impulse input to the activated ECU, for power efficiency and stability measurement purposes. The battery voltage level may drop dramatically to as low as 6 V, while current level will surge beyond 40A during engine startup, then gradually back to nominal level over a few seconds. Hence, an emulator is required with the capability of generating customized voltage pattern, in addition to being able to supply sufficient power for inrush current. Figure 2 illustrate a typical voltage impulse input to the ECU when it is in boost mode. Manufacturers usually create a standard impulse input pattern, with a defined falling/ramping level and speed.

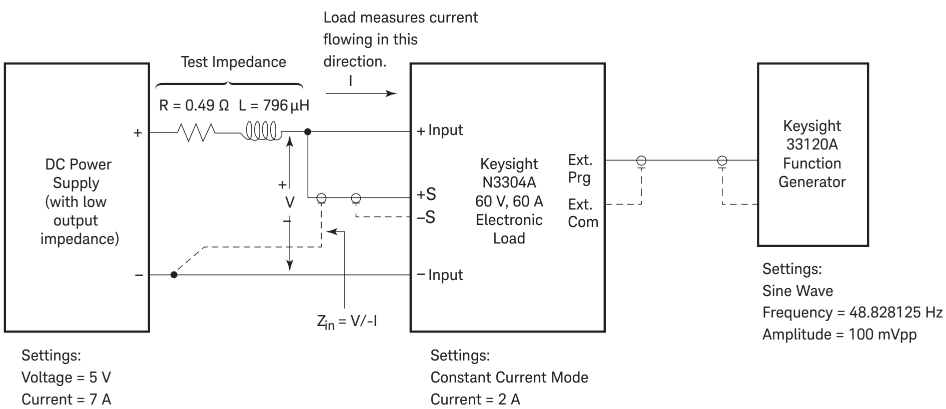

Figure 2. Example of impulse battery voltage pattern

Keysight N7900 series 1 kW/2 kW dynamic DC Power Supplies meet the requirements of a battery emulator for DC-DC ECU. N7951A and N7971A are capable of generating up to 50 A and 100 A power respectively, suitable for automotive ECU applications. Besides, these power supplies feature arbitrary waveform generation, allowing the user to generate customized voltage waveforms with maximum falling speeds of < 200 µs from 20 V to 2 V, sufficient to create the defined battery impulse patterns.

Simulating Loads

In the start-stop system, external passive loads are used to simulate the effect of electronic board networks. Some DC-DC converters have multiple input/output lines to deliver relatively high power levels to loads, depending on the complexity of electronic content in a vehicle. A load switching solution is required, the system must provide the flexibility of load connection and disconnection to establish closed loop circuitry, but also able to tolerate the high current handling and measurements for automotive applications.

Keysight offers a wide range of TS-5000 family load switching cards for various application needs; capabilities include current sensing, fly-back protection, pull-up/pull-down loads, bridge loads, and multiplexed loads etc. The 8-channel heavy duty U7178A load card is recommended, for its high current capabilities that effectively pull loads up to 40 A per output. The card has an over-current protection feature in the event that the ECU fails. For standby/leakage current measurement and lower power load simulation purposes, the 16-channel N9377A can be selected with its dual-load multiplexing selection between jumper and load respectively.

Measurement of Power Efficiency Factor

Power efficiency factor is generally defined as *"Efficiency = VIOutput/VIInput x 100%"*, where *VIOutput* and *VIInput* are the ECU output and input powers correspondingly. Since power is measured as voltage x current, a multimeter is needed to measure voltage and current flow for efficiency calculation. Voltage measurement can be easily obtained by measuring the input/output voltage level reference to ground. However, additional effort is required for high current measurement, instead of using an "ammeter" that only works for low current measurements, a current shunt method usually applies. A current transducer or sensing resistor is required to be installed for voltmeter probing, and eventually the voltage reading will be converted to current using Ohm's Law $V = I \times R$.

The U7178A features current transducers on every single channel, inducing high currents from primary to secondary at the attenuation ratio of 2000:1 with a high-precision 100 Ω resistor for differential voltage measurement. For N9377A, the load card is designed with a current sense resistor of 50 mΩ in series instead. Differential voltage between the sense-resistors and input/output voltage can be measured with the Keysight family digital multimeter – the M9182A DMM PXI was selected in this test with its configurability in a box system using the TS-8989. DMM channels are routed through the TS-5000 family switch matrix cards - the E8792A or E8782A provide access to load cards sense resistors, as well as input and output of the ECU. As a result, power efficiency factors can be obtained using a combination of hardware - load cards, switch matrixes, and M9182A of the TS-5000 family.

The M9182A can also be used for other basic resistance and voltage measurements of open/short and leakage tests.

Measurement of Stability

Output stability validation is required to guarantee the health of ECU during activation. Dynamic DC Power Supply is programmed to generate impulse pattern, measurement of power efficiency factor as well as output voltage will then been obtained at various voltage input levels until the input is stabilized. The Efficiency Factor test methodology has been discussed earlier; while for voltage output, a digitizer is needed to acquire the voltage level throughout boost mode. The digitizer is also used to capture input impulse pattern for verification of desired falling and raising speeds in V/sec. For DC-DC ECU with multiple inputs/outputs, a digitizer with more than two channels is recommended for measuring all inputs and outputs simultaneously. Example of waveforms acquired for DC-DC ECU with one input/output is shown in Figure 3. Note that input and output timings are synchronized.

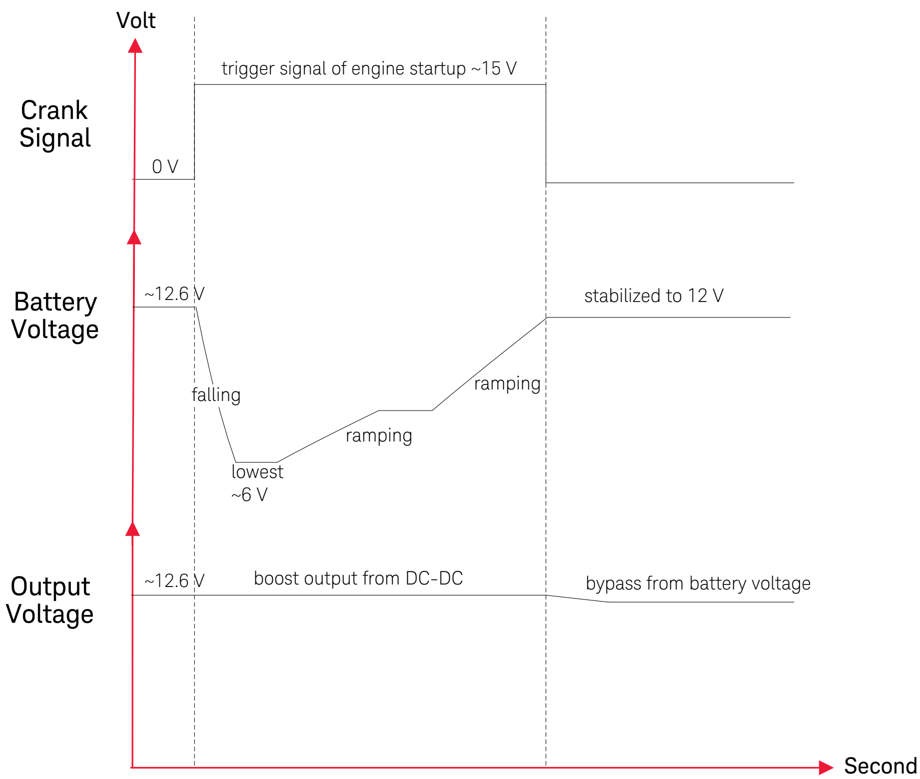

Figure 3. Example of battery input and DC-DC output voltage waveforms acquired by digitizer

Keysight's M9217A PXIe digitizer has two isolated input channels, supporting sampling rates of up to 20MSa/s for simultaneous measurements. The high input voltage at ± 256 V also eliminates the need for input signal attenuation for typical data acquisition instrument with ± 10 V dynamic range. As for multiple input/output ECU, additional 1 x M9217A can be configured to support a total of four isolated channels, synchronized through external or PXI bus trigger. The high speed PXIe M9217A, can be integrated into TS-8989 by enhancing its PXI chassis to a "hybrid" type that supports both PXI and PXIe instrumentation in the near future.

Outlining the Solution

Automotive manufacturers often have to develop their own rack-and-stack test system with custom electronic circuitry and system control software, all of which incur time and expenses. Anticipating these needs from automotive supplier, Keysight offers off-the-shelf PXI/e-based hardware, load switching system and commercial test-executive software as the foundation. The solution uses the following key elements[1] that satisfy DC-DC ECU test requirement:

- Dynamic DC power supply (N7951A or N7971A)
- Switch matrix cards (E8792A or E8782A)
- Load switching cards (U7178A and N9377A)
- PXI digital multimeter (M9182A)
- PXIe digitizer (M9217A)
- PXIe embedded controller (M9037A or M9038A)

Dynamic DC power supply is the only individual LXI compliant box instrumentation used outside the TS-8989 tester. All remaining modular PXI, PXIe and switching cards can be nicely fitted into the TS-8989 eventually when its integrated PXI hybrid chassis is released. The approach enables support of high speed instrumentation (PXIe form) while keeping existing instrumentation setup without migration needs. The modular form factor also provides test engineers the flexibility to mix and match test and measurement hardware needed for a wide range of test requirements.

The system includes the Keysight test-executive software (Keysight TestExec SL) designed specifically for the development and execution of automotive electronic functional testing. Every hardware in the Keysight TS-5000 family is incorporated with its actions and library, for simplicity of hardware control using TestExec SL to accelerate development time. The hardware included is also qualified to work seamlessly with the test executive without compromising compatibility and performance.

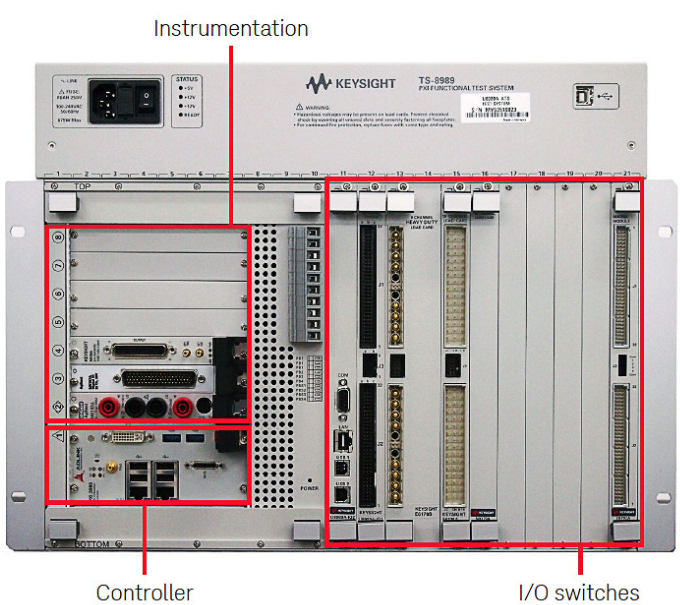

Figure 4. One box TS-8989[2] PXI based tester

1. The instrument list only serves as a general test solution profile, and is not to be used as an ordering guide. Please contact your Keysight sales representative for the best configuration that suits your needs.
2. The new TS-8989 with PXI hybrid chassis, mechanical dimensions and the number of slots are subject to change. The illustrative photo shows a TS-8989 model with PXI-only chassis.

Conclusion

The TS-8989 is an integrated PXI-based system that includes measurements, switching and loads to help manufacturers standardize a solution platform with simplified integration. In addition, the system with its compact size reduces rack space, and this is greatly appreciated by manufacturers with limited facilities for line expansion. By shortening time to market and efficient utilization of space, this compact solution helps to reduce the overall cost of functional testing, and increases competitiveness of automotive ECU manufacturers.

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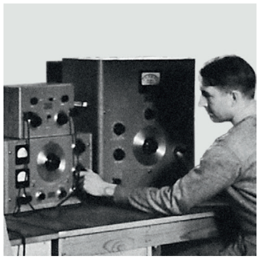
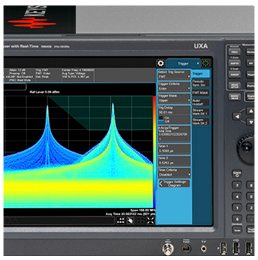


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