Keysight Technologies

Testing Automotive Electronic Parking Brake Controls with Keysight TS-8989 PXI Functional Test System

Application Note

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights

Introduction

Testing Automotive Electronic Parking Brake Controls with Keysight TS-8989 PXI Functional Test System

The electronic parking brake control (EPB) system is replacing the traditional foot pedal or hand lever, utilizing only a control switch with electrical cabling routed to the controller. Drivers can hold their vehicle on a slope at the press of a button, which engages the rear brake system to automatically hold the vehicle at a standstill, and releases the brakes when required. In addition, EPB can be integrated with other vehicle systems, such as drive away assist, hill start assist, and stability control systems that provide comfort, convenience and performance.

EPB functionality relies on the following: control switches input, wheel speed sensor, force sensor and electric motors which monitor various input signals to determine the desired output – such as whether to apply or release the brakes. Figure 1a shows the simplified block diagram of a typical EPB in operation. The functional test setup for a typical EPB will require emulation or simulation for measurement. Figure 1b illustrates the respective models for EPB functional testing:

- Input/Outputs for all test nodes
- Emulation of analog signal for force sensor
- Emulation of frequency signal for wheel speed sensor
- Equivalent loads for electric motors or control switches simulation

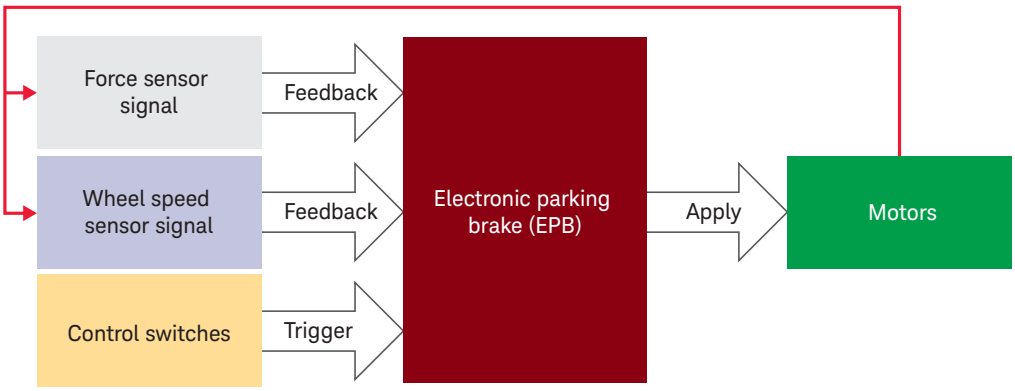

Figure 1a. Simplified block diagram of EPB operation

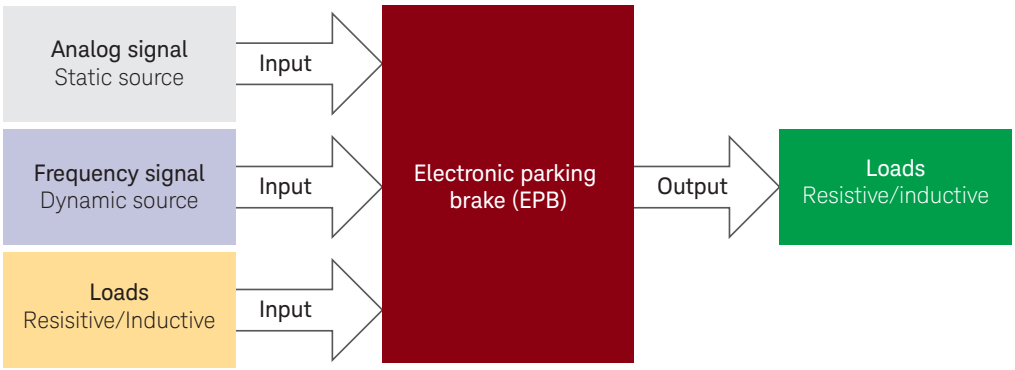

Figure 1b. Respective models for functional testing of EPB functionality

Unlike many other industries, automotive manufacturers often encounter challenges during their test system development phase. Testing of automotive electronic control units (ECUs) typically require high power load emulation, as well as multiple types of signal source for sensor emulation, among other requirements, which are not common in the test solution market. This has resulted in automotive manufacturers having to develops their own rack & stack systems. In the process, they need to invest extra effort on custom circuitry design as well as software development, which may affect the time to market for their products.

The Keysight TS-5000 family test systems are off the shelf systems designed for automotive ECU tests. In this application note, a TS-8989 PXI functional test system will be configured for a typical EPB functional test. Details of system configuration, test methodology and algorithm that help to overcome manufacturers' challenges will be discussed in the following sections.

Input/Outputs

I/O

I/O check is commonly needed for validating electronic control unit (ECU) input and output operations. Simple I/O checks can be easily accomplished by checking for open/short on assembled connector pins. Input tests can be verified by reading the respective states of the ECU for any given digital/analog input. Meanwhile, output tests can be verified by measuring the output signal with triggered states.

Testing

Verification of ECU functionality relies on the ability of the test system to communicate with the ECU. The most common serial interface used in automotive ECU is the ISO-11898 controller area network (CAN) bus protocol. Typically, the ECU designer will determine algorithm to switch the ECU between APPLICATION or TEST mode. Serial communication testing of the ECU can be established using its dedicated communication link under TEST mode operation.

Most ECU tests require a digital multimeter (DMM) to perform I/O checking. The DMM should be able to perform basic operations such as resistance and voltage measurements on each I/O.

Keysight TS-8989 Solution

The TS-8989 system test executive software – TestExec SL (TxSL) has built-in actions and a library that support ISO-11898 from PCI or PXI solution partners. Built-in actions are essentially easy-to-use commands that help to facilitate communication between EPB and the test system. The TxSL includes a software library for the communication devices that have been qualified to work seamlessly on the TS-8989 without compromising compatibility and performance. Every Keysight TS-5000 family's hardware is incorporated with actions and a library for simplicity of hardware control using TxSL.

TS-8989 features an option of a PXI 6½-digit DMM M9182A (4.5k reading/sec) or M9183A (15k reading/sec) for resistance or voltage measurements. Using the DMM M918xA action library, the user will call simple high level TxSL actions for resistance or voltage measurements respectively as per the example below:

Resistance Measurement	
dmmMeas2WResEx	Measures 2-wire resistance
dmmMeas4WResEx	Measures 4-wire resistance
Voltage Measurement	
dmmMeasureDCV	Measures DC Voltage

The DMM channels are routed through the E8792A or E8782A pin matrix card that connects to the EPB device-under-test (DUT). Every pin matrix card has four analog buses, and up to 64 rows to access every single node of the EPB – refer to figure 2. A software switching manager, incorporated in TxSL, streamlines the matrix switching programming via the Switching-Path-Editor tool. This tool tracks every subsequent relay state from existing relay nodes without the need for referencing comprehensive and complex routing architecture; thereby helping to speed up programming time, in addition to avoiding syntax error. Figure 3 illustrates an example on how to port in switching connections easily via the TxSL Switching-Path-Editor.

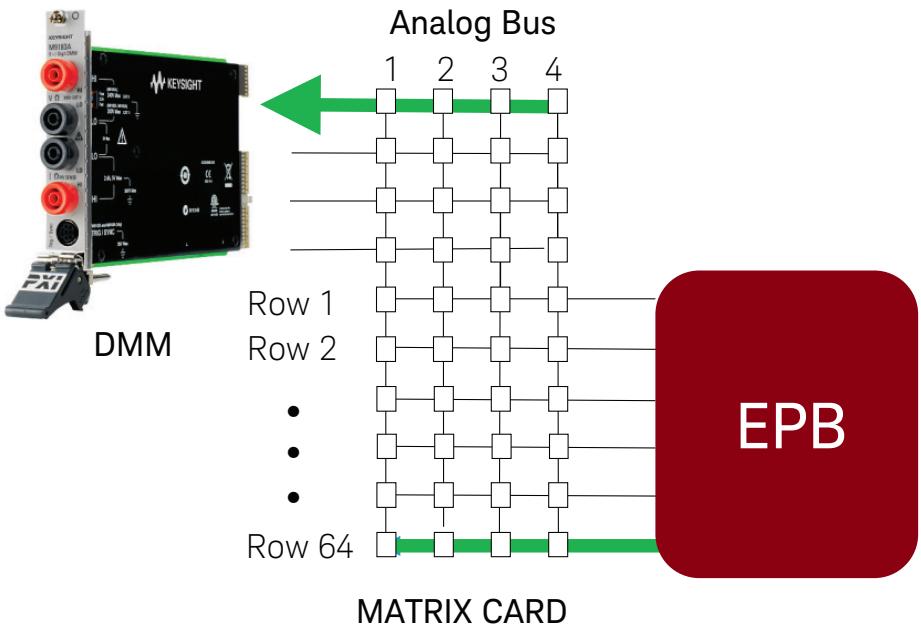

Figure 2. Pin matrix card connection for DMM accessibility

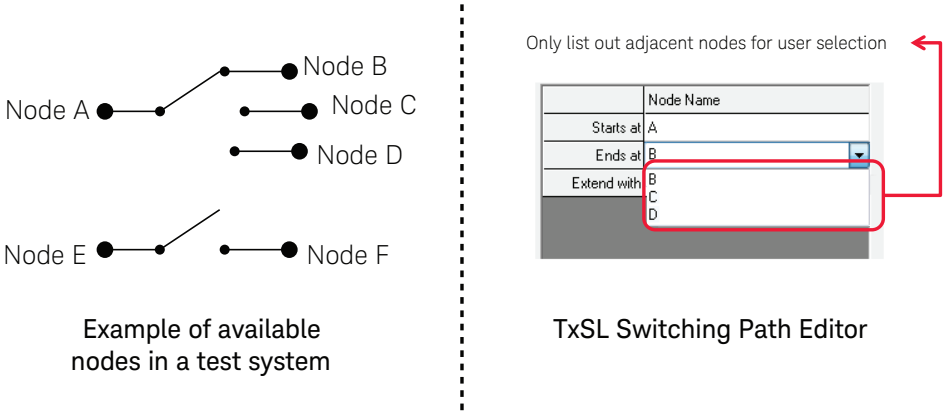

Figure 3. An example of using TxSL Switching-Path-Editor

Analog Signal

Force sensor

The Hall Effect force sensor is used to measure the clamping force in the EPB system. The sensor is key to calculating the amount of force that needs to be applied in order to keep the vehicle static while it is stationary. The actuator uses a close loop control, whereby the EPB uses feedback from the sensor to supply sufficient electric motor torque on the brake pad.

Testing

Depending on the force sensor type, the typical voltage level of ranges from 0 to 5 volts. Therefore, simulation of a static voltage input is required at the force sensor signal pin. In functional testing or product characterization, the default voltage inputs, or sweep of voltage inputs are applied for verification by reading the EPB states under TEST mode.

Keysight TS-8989 solution

The system can be configured with a M9188A PXI dynamic digital analog convertor (DAC) for this test. In order to emulate the force sensor effect, the M9188A may be programmed to generate various voltage levels to the EPB depending on the desired input. Below is a sampling sequence of TestExec SL actions for the M9188A to generate DC voltages:

dac_ConfigClockSource	Specifies the source for system clock of the module (select internal clock)
dac_ConfigTrigger	Configure Trigger and Events setting of the module (select software trigger)
dac_ConfigDCOutputSingleChannel	Configure module output to DC for single channel (set channel 1 voltage)
dac_ConfigOutputRelaySingleChannel	Configure module output relay for each channel (enable channel 1 output)
dac_InitTrigger	Initiate Triggering of the module
dac_SendSoftwareTrigger	Send software trigger to the module

Frequency Signal

Wheel Speed Sensor

The wheel speed sensor is necessary for auto-hold function of the EPB system and quantifies the rotational velocity of the wheels on the vehicle. The frequency generated by this sensor is directly proportional to the velocity; hence frequency detection from the sensor indicates if a particular wheel is moving, whether desired or otherwise.

Testing

The waveform generated by the wheel speed sensor is a current pulse wave typically from 7 mA ILow to 14 mA IHigh with a frequency range from 10 Hz to a few kHz. A frequency generator is required to emulate the sensor signal to the EPB receiver. Similar to analog input signal testing, default frequency input or sweep of frequency input may be applied for EPB functionality check. Figure 4 shows an example of a typical 1 kHz waveform generated by a wheel speed sensor.

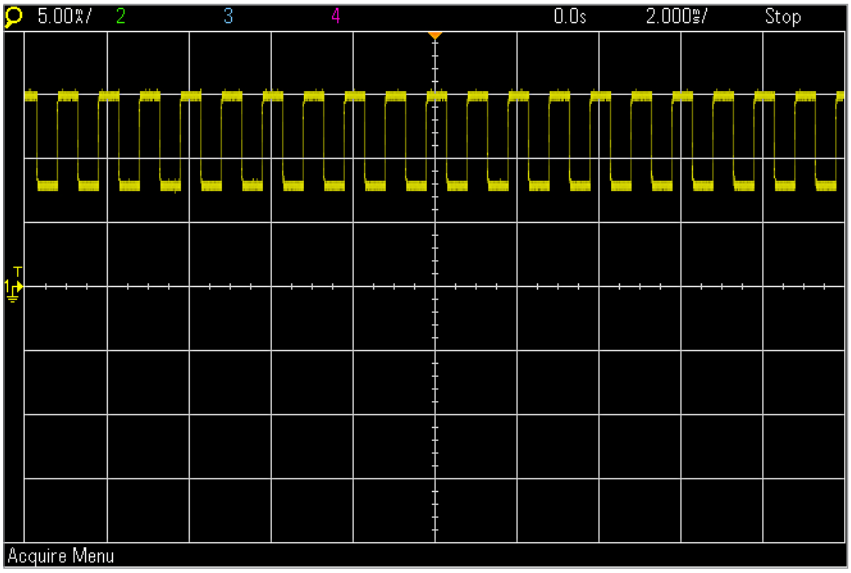

Figure 4. 1 kHz current pulse signal generated by a wheel speed sensor

Keysight TS-8989 solution

The M9188A dynamic DAC is capable of generating both voltage and current source with 500 kSa/s update rate. Waveforms can be programmed with M9188A to be symmetric or asymmetric, depending on the desired input. For wheel-speed sensor signal emulation, the M9188A is programmed to generate an asymmetric current pulse signal to the EPB. This solution significantly reduces the EPB cost of test that conventionally requires configurations of at least one unit of voltage source and another unit of frequency generator for both analog and frequency input signal testing. The sampling of TxSL actions in the library for the M9188A for waveform generation is as follows:

dac_ConfigStdWaveformSingleChannel	Configure standard waveform for single channel (configure current mode square wave signal on channel 1)
dac_ConfigOutputRelaySingleChannel	Configure output relay for each channel (enable channel 1 output)
dac_InitTrigger	Initiate Triggering of the module
dac_SendSoftwareTrigger	Send software trigger to the module

Load Switching

Electric motors

Activation/deactivation of brakes with EPB requires an actuator that works with the electric motor. When the electric motor is powered on, it rotates and actuates gears that provide force that is applied on both the rear brakes, thereby keeping the vehicle motionless. To release the brakes, the motor rotation direction is reversed to remove the applied force.

Testing

The EPB will generate a high power source to drive the electric motors to ensure that the motors are supplied with sufficient torque which will be applied on the brake pads when brake activation is triggered. Therefore, these motors are usually tested at high current levels. The switching solution must not only provide the flexibility of load connection and disconnection to establish closed loop circuitry, but also able to tolerate the high current handling and measurements that range from 10 A to 20 A.

Keysight TS-8989 solution

In a high-mix test environment, the manufacturer would usually prefer a switch-in-system design because it promotes the reusability and scalability of switches on the system. TS-8989 system offers a wide range of load switching cards for various application needs.

In this test, the 8-channel heavy duty E6178B load card is selected for its high current capabilities. The E6178B load card option has current ratings to effectively test the motor driver despite over-current levels of up to 30 A. In addition, the card has an over-current protection feature in the event that the motor driver fails.

The E6178B features current transducers on each channel, inducing high currents from primary to secondary at the attenuation ratio of 1000:1. The secondary current transducer is connected with a high-precision 75-Ohm resister in series for current monitoring purposes. Voltage drops across the resistor are measured with the M9182A or M9183A PXI DMM, and the results are then converted into current using the equation of Ich = Vdrop / 0.075. Figure 5 shows the architecture of an E6178B channel that illustrates its circuit protection and current sense capabilities.

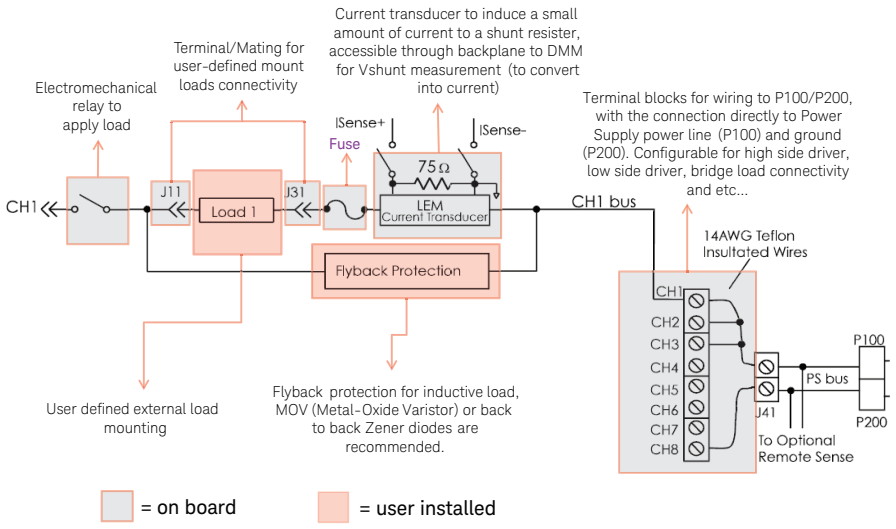

Figure 5. E6178B load switching channel 1

Full Configuration

In addition to instruments used for the specific tests described in this paper, other instruments will or may be required to complete the system for EPB functional testing. For instance, a programmable power supply is a required to power up the DUT. Additional pin cards may be needed for EPB designs with higher node counts. Additional low current load cards will be desirable for control switches or any other load switching requirement. Lastly, additional digital input/output (DIO) may be required for DUT fixture control and automation.

In summary, a typical EPB functional test can be fulfilled with the following equipment[1]:

- PC Controller with test sequencer
- DMM
- Dynamic DAC
- DIO
- Pin matrix cards
- Load switching cards
- CAN communication card
- Programmable power supply

The above instruments can be configured with Keysight TS-8989 solution. All instrument and cards are fitted into the TS-8989 one-box tester – Figure 6, with a programmable power supply stacked either on top or at the bottom. The TS-8989 one box PXI-based system provides engineers with the flexibility to mix and match a variety of PXI instruments, power supplies, switch matrix and load card options to meet all possible DUT test requirements. In addition, the compact system size effectively improves integration flexibility and reduces rack space needs, leading to a leaner manufacturing environment.

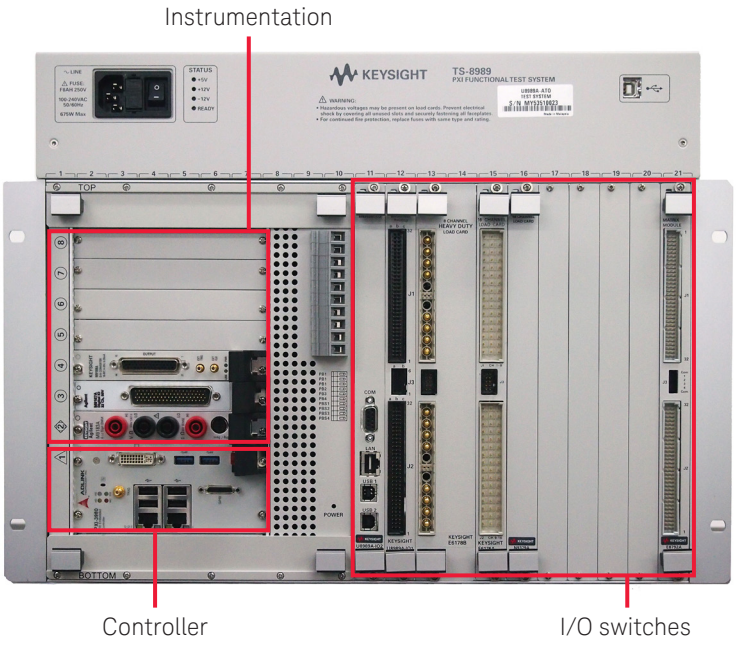

Figure 6. TS-8989 solution

1. This 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.

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