

Testing Dual Airbag Inflators and Modules with the Model 2790 SourceMeter® Switch System

Introduction

A typical airbag inflator is a two-terminal device in a metal housing and is used to initiate the deployment of the bag in an automobile crash. Modern passenger restraint systems incorporate a dual inflator, which allows for variable inflation rates, depending on the speed of the vehicle crash. One inflator is used to deploy the bag for low speed scenarios; the other is used for higher speed collisions.

The pyrotechnic device that actually triggers the gas discharge, which inflates the airbag, is called an initiator. The resistance of the initiator is a valid indication of a good device. Testing the initiator is much like testing a fuse; if too high a current is used, the fuse will open up and must be scrapped. For an initiator, the test current must be kept below some specified level to prevent activating the inflator prematurely, which would not only destroy the DUT, but also presents a potential hazard. An initiator must be electrically isolated from the inflator housing because excessive leakage current between the housing and the initiator can prevent proper operation of the device. Consequently, an airbag module requires two resistance measurements. One test (for the initiator) measures a relatively low resistance using a limited test current; the other test (for isolation) measures a relatively high resistance using a moderately high voltage.

Another Keithley Application Note (Number 2194) describes an airbag inflator test system based on Keithley's Model 2410 SourceMeter and Model 7001/7002 Switch Systems. The Model 2790 system described here combines all of the switch, source, and measure functions required for high throughput testing of the necessary electrical characteristics of an airbag assembly in a single instrument.

Test Description

Bridgewire Test

The airbag inflator has two terminals connected to the initiator or, as it is commonly called, the bridgewire. The bridgewire is coated with a primer that ignites when sufficient current passes through the wire. Dual inflators have two bridgewires and each wire is tested separately. The resistance of a bridgewire is typically about 2Ω . The bridgewire is tested by sourcing a current through it and measuring the resulting voltage drop across it. The resistance of the bridgewire is calculated using Ohm's Law. To avoid unintended ignition, the level of test current applied is typically 50mA or less; therefore, the voltage to be measured is

100mV or less. A four-wire connection must be used to ensure reasonable accuracy for this test. For more information, refer to the section titled "Lead Resistance."

Insulation Resistance (HIPOT) Test

The insulation resistance between each of the initiators and the housing must be verified. Typical specifications for the insulation resistance range from $10M\Omega$ to $100M\Omega$ minimum. This test is performed by applying a voltage between one of the leads of each bridgewire and the housing, and measuring the resulting current. Ohm's Law is used to calculate the insulation resistance. The test voltage is typically 500V; therefore, the current to be measured is $50\mu A$ or less.

Shunt Bar (Shorting Clip) Test

To prevent accidental ignition due to static discharge while the device is being handled or installed in the vehicle, a shunt bar or shorting clip is typically installed across the inflator terminals. The shunt must be opened or removed to test the bridgewire properly, but it can be in place during the HIPOT test. It is common practice to measure the resistance of the installed shunt bar, which is typically $10\text{--}100m\Omega$. The test current used to measure the shunt bar should be no more than 50mA so that a defective shunt bar will not result in ignition. Again, a four-wire connection must be used when making this measurement. Sometimes, it is preferable to make this measurement under dry circuit conditions to avoid penetrating any oxides that may develop on the contact surfaces of the shunt. If the test breaks down the oxide layer, the measured resistance could be lower than what actually exists in normal usage. Dry circuit testing requires that the voltage developed across the DUT be limited to 20mV or less. The shunt bar is often tested several times during an inflator test sequence: at the start to verify that it is functional, prior to the HIPOT test to ensure the bridgewire is protected, and at the end of the sequence to verify that it is properly installed and that the inflator is safe to handle.

Contact Verification

To perform the insulation resistance test, contact must be made to the airbag inflator housing as described previously. If the test fixture does not make contact with the housing and the test is performed, the measured resistance will be that of an open circuit rather than the true insulation resistance. Both good and bad contact can produce passing results, but the open circuit result is clearly invalid. Two contact points are used to verify that contact is being made with the metal housing. The resistance between these two contact points is measured. If the result is a compar-

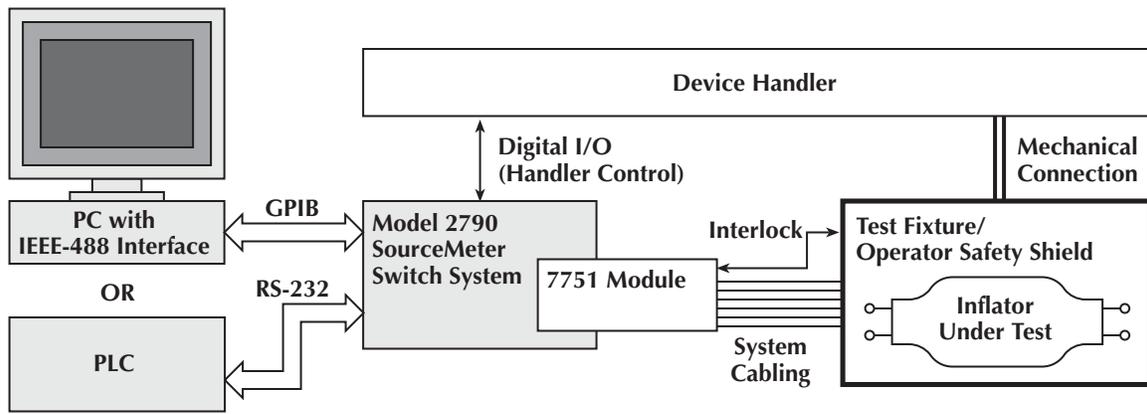


Figure 1. Typical Dual Inflator Test System

tively low value, then it is generally safe to assume proper contact has been made.

Test System Description

The Model 2790 SourceMeter® Switch System with a single Model 7751 plug-in module is capable of making all of the measurements outlined in this note. The 2790 mainframe is a full-featured 6½-digit DMM with two rear slots for plug-in modules. Compatible modules add switching for signal routing, as well as additional source and measure capabilities. Although this note focuses on using the 7751 module for inflator testing, two other modules are available for added flexibility. The Model 7752 module is identical to the 7751, except that it does not include the high voltage source and current-to-voltage converter, and the Model 7702 is a general purpose 40-channel multiplexer. The Model 7751 module includes programmable DC voltage (50–500V) and current (0–50mA) sources as well as relay switching. Four banks of two-pole relays provide a sufficient number of terminals to connect two single inflator units or one dual inflator unit to the 2790 for test. The mainframe will accommodate two plug-in modules, so a single 2790 system can be connected to two test stands and be used to test two dual inflator airbag modules. Parallel testing in the form of “voltage soak with one card, measure with the other” is possible for both single and double test stand configurations. The current-to-voltage converter on the 7751 module is used with the voltage source to measure the insulation resistance. It can be used to measure currents from 0–50µA. The 7751’s switch matrix simplifies implementing the contact verification tests discussed previously and allows the DMM to verify test voltages and currents for increased measurement reliability. Safety related design features that provide added protection against accidental detonation include low energy sources, a hardware source interlock, and programmable shunts that can be used in conjunction with an inflator’s shunt bar. These features are discussed in detail in the section titled “Test System Safety.”

Figure 1 illustrates a typical hardware configuration for an airbag inflator test system using a Model 2790. In automated

manufacturing systems, programmable logic controllers (PLCs) are often used for process control, rather than PCs. Most of today’s PLCs do not offer GPIB modules, so system control must be done over the serial (RS-232) bus. The Model 2790 has both GPIB and RS-232 interfaces, so it’s suitable for use with both PC and PLC controlled test systems.

All of the switching required to connect the sources and measurement circuitry to the inflator is contained on the 7751 module. Cabling from the test stand is connected to the 7751 module via screw terminals. Figure 2 shows a typical connection scheme for testing a dual inflator. Relay channels 1 through 9 connect signals to and from the various parts of the inflator DUT, depending on which test is being performed. Channels 10 through 12 (Bank 4) are also available for connecting to the

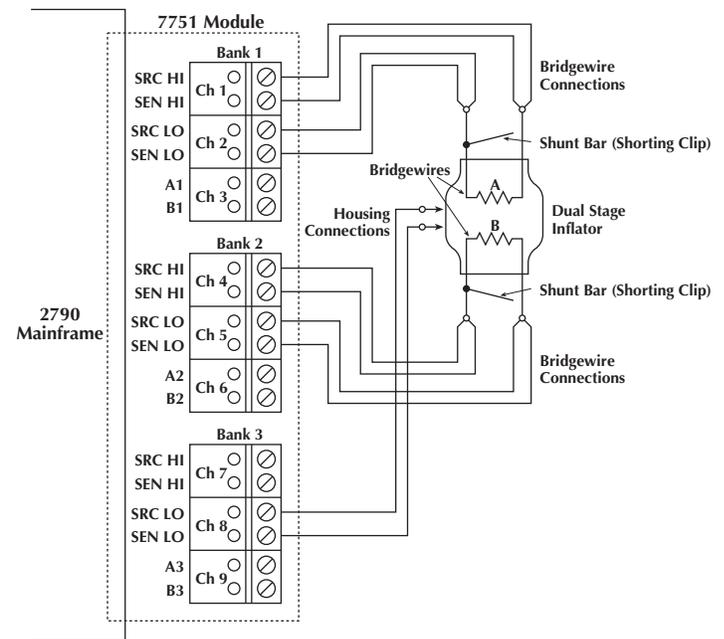


Figure 2. Typical Connections Between 7751 and a Dual Inflator Module

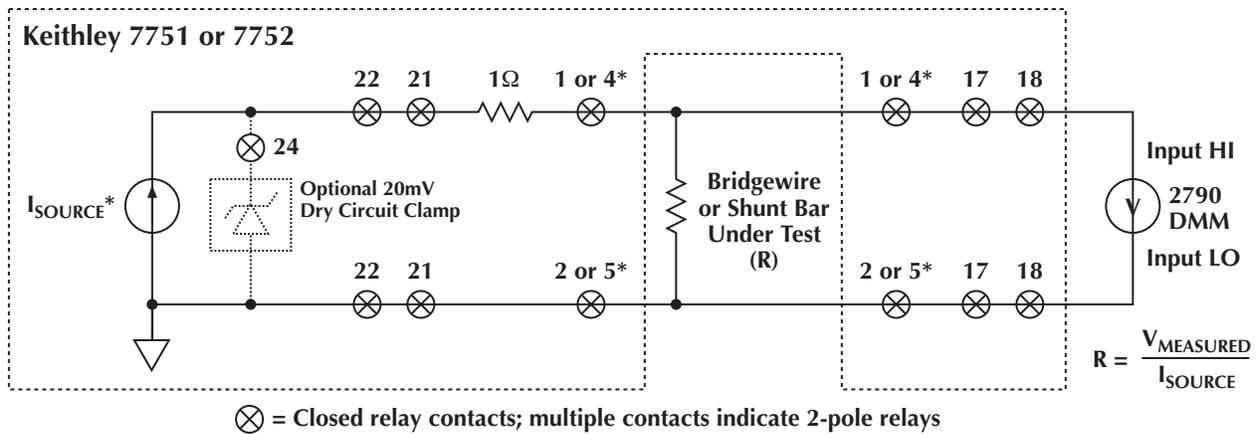


Figure 3. Circuit Configuration for Testing Bridgewire and Shunt Bar

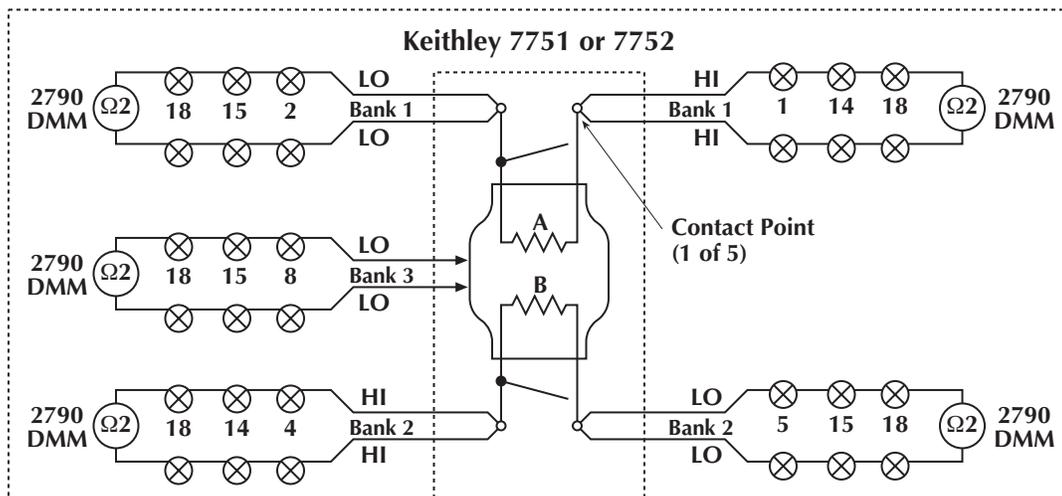


Figure 4. Circuit Configurations for Contact Verification (Housing and Four-Wire Source/Sense Connections)

DUT, but they are not used in this example. Additional relay channels control the interconnection of the DUT channels and the voltage and current sources, the voltage-to-current converter, and the DMM. The terminal labels shown in this figure (and present on the card) reflect the typical functional connection in a four-wire resistance measurement, but because of the remarkable flexibility of this module, the actual internal connections will vary, depending on the signal routings chosen. For example, the leads connected to Ch 8 in the figure are from the two connection points on the housing. For contact verification, these terminals are routed to the INPUT HI and LO terminals of the 2790 DMM so that a two-wire resistance measurement can verify that both contacts are electrically connected to the housing.

Given the connections shown in **Figure 2**, **Figures 3** through **5** show the test circuits for the various tests that have been addressed. **Figure 3** shows the circuit for testing either the bridgewire or the shunt. Open relay channel 22 and close channels 1, 2, and 21 to select the current source and connect it to either bridgewire A or shunt A (if it is in place). Channel 22 is a Form C relay, and the current source is selected when it is in the normally open position. The DMM is connected across the bridgewire or the shunt by closing relay channels 1, 2, 17, and

18. To test bridgewire B and shunt B, close channels 4 and 5 instead of 1 and 2. This is a four-wire resistance measurement configuration, which ensures that the resistance of the connecting leads is not included in the measured value of the bridgewire or shunt resistance. The resistance calculation shown in the figure can be performed internally by the 2790 by selecting the S11OHMS math function (assuming the module is in Slot 1). The calculation uses the programmed level of the current source. It is possible to close a different group of relays and connect the DMM across the 1Ω resistor and measure the voltage drop. The measured voltage can be used to verify that the programmed current is actually being sourced. This measured current can also be used to calculate the DUT resistance manually. As mentioned previously, it is possible to connect a 20mV dry circuit clamp across the DUT. This feature, which is enabled by closing channel 24, can be used to prevent the breakdown of oxide layers on the shunt bar and/or to reduce the possibility of accidental detonation further. If the clamp is used, the current source output is limited to a maximum of 1mA.

Figure 4 shows the test setup for performing contact verification. The wiring diagram in **Figure 2** shows two leads connected to each bridgewire (or shunt) terminal and to the housing.

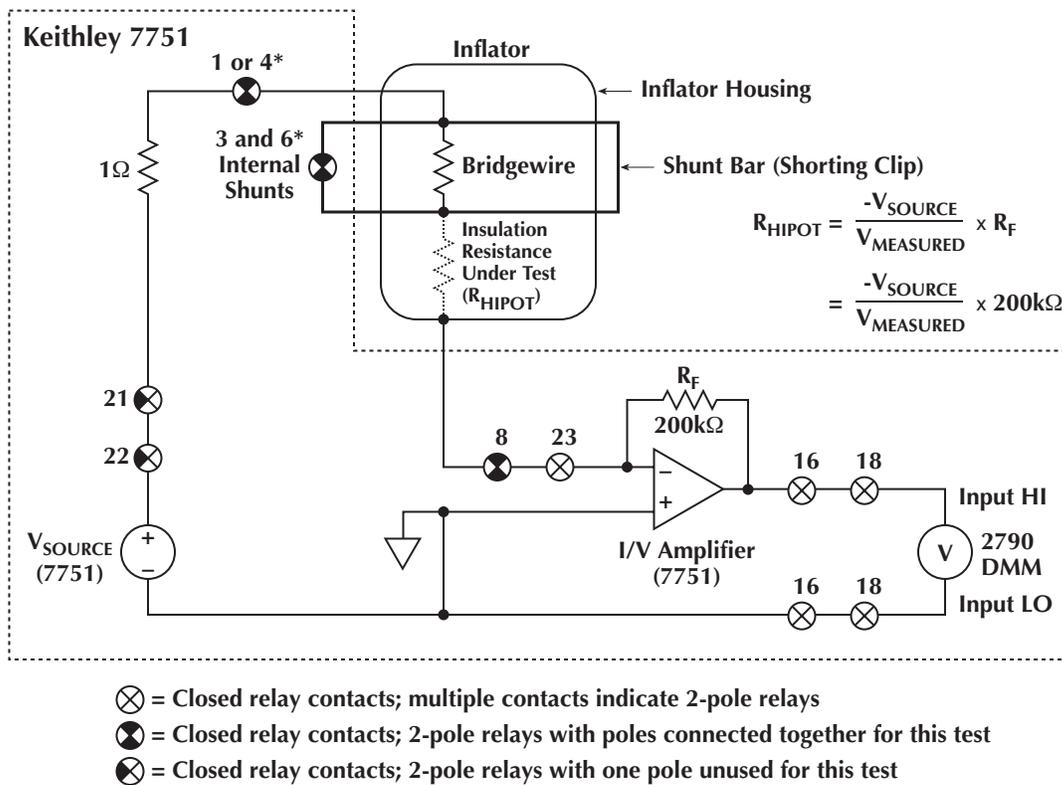


Figure 5. Circuit Configuration for Testing Insulation Resistance

By closing the different combinations of relays identified in Figure 4, it is possible to perform a two-wire ohms measurement on each pair of leads and verify good electrical contact. If both wires are electrically connected together, the resulting measurement can range from approximately 12Ω to several tens of ohms, depending on the type and length of the connecting cables. The minimum of approximately 12Ω is due to the internal circuitry of the switch modules. If the measured resistance is significantly higher, then it is likely that one or both of the leads are not contacting the terminals or housing.

Figure 5 shows the test circuit for measuring the insulation resistance. Close relay channels 1, 21, and 22 to select the voltage source and connect it to one terminal of bridgewire A. The voltage source is selected when the channel 22 relay is in the normally closed position. Given that the resistance of a good bridgewire is much less than the leakage resistance being measured, it is necessary to perform this test at only one of the bridgewire terminals. Close relay channels 8 and 23 to connect the housing to the current-to-voltage converter (I/V Amplifier). Finally, connect the output of the current-to-voltage converter to the DMM by closing relay channels 16 and 18. To measure the insulation resistance between bridgewire B and the housing, close channel 4 instead of 1. A two-wire resistance measurement configuration can be used in this case because the resistance of the test leads is insignificant compared to the leakage resistance. The resistance calculation shown in the figure can be performed internally by the 2790 by selecting the S1VOHMS math function (assuming the module is in Slot 1). The current-to-voltage con-

verter is an inverting amplifier, so a positive current will produce a negative output voltage. The minus sign in the calculation ensures that positive resistances are displayed. Note that the calculation uses the programmed level of the voltage source. It is possible to close a different group of relays to connect the DMM across the voltage source and measure its output to verify that the programmed voltage is actually being applied to the DUT. This measured voltage can also be used to calculate the leakage resistance manually.

Figure 5 shows the shunt bar (shorting clip) connected across the bridgewire. Some manufacturers prefer measuring the insulation resistance when the shunt bar is connected because it is almost impossible to inflate the airbag with the short in place. The 7751 module has four relay-selectable shunts (channels 3, 6, 9, and 12) that can be used along with the inflator shunt bars for added reliability. Figure 6 shows one possible connection scheme for using the 7751 module's integral shunts. As depicted in Figure 5, closing relay channels 3 and/or 6 connects the additional shunts across bridgewires A and/or B during the insulation test.

Test System Safety

When designing an inflator test system, the user should note that airbag inflators are explosive and therefore dangerous. Even if the test system is designed with sufficient safeguards, a defective device under test could detonate under normal testing conditions. Test system designers must be aware of the hazards involved

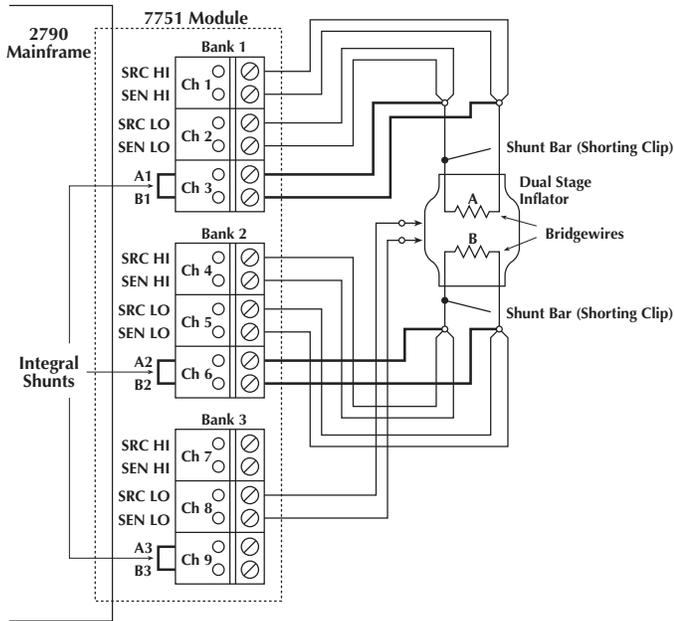


Figure 6. Typical Connections for Using 7751 Shunts During Inflato Testing

with this application and design the test fixtures such that sufficient protection is available for themselves, operators, or maintenance personnel in the event of an unintentional detonation of an inflator. Sufficient protection must be provided to personnel against any hazardous voltages that may be present as well. It is also the responsibility of system designers to make sure that all personnel are trained in the safe use of the test system.

Keithley has incorporated many design features in the 2790 SourceMeter Switch System and the 7751 module that make this inflator test system inherently less likely to cause an initiator detonation than previous test solutions. Significant steps have been taken to limit the power applied to the device under test, even under single fault conditions (e.g., programming error or test instrument failure). Design features that enhance the reliability of the 2790 system include a low energy, high voltage source, a low voltage compliance (5.5V) current source, and automatic cable discharge circuitry. A hardware source interlock is also available and is discussed in the section titled “Methods and Techniques/Handler Interface.” The high voltage source cannot be programmed to output more than 500V, and at this level, internal impedances limit the current output to less than 1mA under short circuit conditions. Even under single fault conditions, the voltage is clamped at 600V and the steady state current is limited to less than 2mA.

Capacitance between signal paths on the 7751 module and in cables connecting the inflator to the module can store a charge from the voltage source. Whenever the voltage source is disconnected from the switch matrix by opening channel 22, 100kΩ shunts are automatically connected between the Source HI and LO lines and the Sense HI and LO lines for 5ms to bleed off any residual charge. The discharge circuitry can also be controlled

directly to allow the user to discharge the cables for more than 5ms, or at other times during the test sequence. **NOTE: In order to discharge any connecting cables, the relays connected to the cables should not be opened until after the voltage source has been disconnected from the signal lines. Using the “OPEN ALL CHANNELS” command from the front panel or under remote control automatically opens Channel 21 and then Channel 22 five milliseconds before opening any other channels. Caution: Do not connect the voltage source HI to earth ground. Doing so will effectively connect an internal capacitance of 1nF across the Vsource HI and LO, which could cause the capacitor to be discharged across the DUT if proper precautions are not taken.**

The current source cannot be programmed to output more than 50mA. The open circuit voltage of this source is 5.5V. Under single fault conditions, the output current is limited first by redundant active current limiters and ultimately by dual 62mA fuses. The fast response of the active limiters minimizes the duration of any initial transients. As mentioned previously, a dry circuit clamp can be connected across the output of the current source to limit the DUT voltage to 20mV.

NOTE: Operators and maintenance personnel must be protected from injury under fault conditions (e.g., software error, controller error, instrument failure, system overloads). Use appropriate guards, shields, and insulators on external connections to protect any user or maintenance personnel from risk of electric shock or mechanical injury.

Methods and Techniques

Handler Interface – Digital I/O

The 2790’s built-in digital interface is capable of controlling the device handler equipment directly. The digital interface connector contains five TTL-compatible digital outputs and two inputs, as well as connections for externally powered relays and ground. The five outputs provide test pass/fail notification. Two high limits and two low limits can be defined globally for any DMM measurement. They can also be defined separately for each measurement channel. This last feature does not apply to the 7751 and 7752 modules because none of the channels are defined strictly as measurement channels. It is possible, however, to assign limits on a per channel basis if the available 7702 module is used. Each limit is tied to a different digital output. The fifth digital output is a master limit, which is the logical “OR” of the other four lines. The logic sense of the five digital outputs can be set to either high true or low true. The outputs can be used to control external relays with coil voltages from 5V to 33V. Each digital output has an internal flyback diode for protection when switching inductive loads. Connection to the diodes is via Pin 7 of the digital I/O connector.

The two digital inputs both relate to external triggers. One input is for an external trigger and the other is a trigger interlock. Applying a TTL low (0V) to the trigger interlock pin or shorting

it to ground locks out or disables external triggers. Applying a TTL high (5V) to the trigger interlock pin, or leaving it open circuited, enables external triggers. For example, when controlling a scan using external triggers, this trigger interlock feature can be used to prevent a scan from proceeding if a safety shield is open by having the handler provide the appropriate signal.

Handler Interface – Trigger Link

The Trigger Link connector on the 2790 has one TTL-compatible digital input, one digital output, and two ground lines. The input is for an external trigger. It is the same as the trigger input of the digital I/O connector. The output provides a trigger signal upon completion of a 2790 DMM measurement and can be used to signal a handler that a test is finished.

Handler Interface – 7751/7752 Interlock

The 7751 and 7752 modules have their own interlock circuits, which provide a more effective interlock for use with safety shields. Open circuiting the interlock terminals opens relay channels 18, 19, and 21 on the 7751 and 7752 modules and prevents them from being closed. The current and voltage (7751 only) sources are disconnected from the signal lines, as is the 2790 measurement backplane. To close these channels, a short circuit must be applied to the interlock terminals. Connecting a switch to the 7751/7752 interlock that opens the interlock circuit whenever the handler's safety shield is opened or closes the interlock circuit when the safety shield is closed is an appropriate method for using this feature.

Basic Programming Guidelines

The following sections provide the remote programming commands needed to configure the 2790 and perform all of the tests described in this application note. The tests are implemented for the connection scheme shown in **Figure 6**. It is assumed that the 7751 module is in Slot 1 of the 2790 mainframe. The internal shunts on the 7751 module are always connected unless a particular bridgewire or shunt bar is being tested. Each section contains all of the configuration commands necessary to perform that particular test. If upon completion of a test the instrument is already configured properly for the next test, then clearly it is not necessary to send commands that do not change any settings. Such commands are included here only so each test can be performed independent of the others.

The command strings are sent to the Model 2790 via either the GPIB or RS-232 communication interface to execute an inflator test. Use the 2790's front panel controls to select the bus the instrument will use. Once the communication protocol is selected, it is saved as a default in nonvolatile memory until it is changed again. To set the protocol using the front panel controls, press and release SHIFT and then press either GPIB or RS-232. If the selected interface is OFF, use the left/right arrow keys to select the ON/OFF setting (flashes when selected). Use the up/down range keys to change the setting to ON and then press ENTER. Use the same keys to change communication parameters like GPIB address or RS-232 baud rate, pressing ENTER to accept each setting. Be sure the INPUTS FRONT/REAR switch is set to REAR (pushed in) to route signals through the plug-in module to the DMM.

Reset Hardware and set global data format

```
Send 2790 ("*RST")           ' Reset instrument and put in one-shot measurement mode
Send 2790 ("FORM:ELEM READ") ' Send only the reading values to the PC when queried;
```

Configure and perform Contact Verification

Note: Relays identified in channel list are closed sequentially in the order they appear in the list. Typically, only contact with the housing is verified, but the 2790 makes checking the complete system a simple process.

```
Send 2790 ("ROUT:MULT:CLOS (@103,106)") ' Connect internal shunts across DUT
Send 2790 ("SENS:FUNC 'RES'")          ' Set DMM to 2-wire Ohms
Send 2790 ("SENS:RES:RANG 100")        ' Set resistance range to 100 Ohms
Send 2790 ("SENS:RES:NPLC 1")          ' Set integration time to 1 power line cycle
Send 2790 ("ROUT:MULT:CLOS (@101,114,118)") ' Connect Bridgewire A HI leads to DMM
Send 2790 ("READ?")                   ' Initialize 2790 and ask for data (triggers a measurement)
Enter 2700 (Data String)               ' Enter data into PC from Model 2790; value is a
                                        resistance
Inspect Data for Pass/Fail – Continue if pass, take appropriate action and repeat test if fail
Send 2790 ("ROUT:MULT:OPEN (@101)")     ' Disconnect Bridgewire A HI leads from DMM
Send 2790 ("ROUT:MULT:CLOS (@104)")     ' Connect Bridgewire B HI leads to DMM
Send 2790 ("READ?")                   ' Initialize 2790 and ask for data (triggers a measurement)
Enter 2700 (Data String)               ' Enter data into PC from Model 2790; value is a
                                        resistance
Inspect Data for Pass/Fail – Continue if pass, take appropriate action and repeat test if fail
Send 2790 ("ROUT:MULT:OPEN (@104,114)") ' Disconnect Bridgewire B HI leads from DMM
Send 2790 ("ROUT:MULT:CLOS (@102,115)") ' Connect Bridgewire A LO leads to DMM
Send 2790 ("READ?")                   ' Initialize 2790 and ask for data (triggers a measurement)
Enter 2700 (Data String)               ' Enter data into PC from Model 2790; value is a
                                        resistance
Inspect Data for Pass/Fail – Continue if pass, take appropriate action and repeat test if fail
Send 2790 ("ROUT:MULT:OPEN (@102)")     ' Disconnect Bridgewire A LO leads from DMM
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Send 2790 ("ROUT:MULT:CLOS (@105)") ' Connect Bridgewire B LO leads to DMM
Send 2790 ("READ?") ' Initialize 2790 and ask for data (triggers a measurement)
Enter 2700 (Data String) ' Enter data into PC from Model 2790; value is a
                             resistance
Inspect Data for Pass/Fail – Continue if pass, take appropriate action and repeat test if fail
Send 2790 ("ROUT:MULT:OPEN (@105)") ' Disconnect Bridgewire B LO leads from DMM
Send 2790 ("ROUT:MULT:CLOS (@108)") ' Connect Housing LO leads to DMM
Send 2790 ("READ?") ' Initialize 2790 and ask for data (triggers a measurement)
Enter 2700 (Data String) ' Enter data into PC from Model 2790; value is a
                             resistance
Inspect Data for Pass/Fail – Continue if pass, take appropriate action and repeat test if fail
Send 2790 ("ROUT:MULT:OPEN (@108,115,118)") ' Disconnect Housing LO leads from DMM; internal shunts
                                             still connected

```

Configure and perform Shunt Bar (Shorting Clip) tests

Note: First shunt bar tested without dry circuit, second tested with dry circuit. At end of test the internal shunts are left connected to the DUT. Use ROUT:OPEN:ALL if going to disconnect DUT from test system. Also, selecting SII ohms math function automatically sets the measurement function to DC Volts and measurement range to IV.

```

Send 2790 ("ROUT:MULT:CLOS (@103,106)") ' Connect internal shunts across DUT
Send 2790 ("ROUT:MULT:OPEN (@122)") ' Select I-source; default setting
Send 2790 ("SOUR:CURR 0.05, (@127)") ' Set Current Source level to 50 mA
Send 2790 ("CALC1:FORM S1I") ' Use low ohms (source I measure V) math function to
                               calculate resistance
Send 2790 ("SENS:VOLT:NPLC 1") ' Set integration time to 1 power line cycle
Send 2790 ("CALC1:STAT ON") ' Enable the math function
Send 2790 ("ROUT:MULT:CLOS (@101,102,117,118,121)")
                               ' Connect Shunt Bar A to Current Source and DMM
Send 2790 ("ROUT:MULT:OPEN (@103)") ' Disconnect internal shunt from Shunt Bar A
Send 2790 ("READ?") ' Initialize 2790 and ask for data (triggers a measurement)
Send 2790 ("ROUT:MULT:CLOS (@103)") ' Reconnect internal shunt across Shunt Bar A
Enter 2700 (Data String) ' Enter data into PC from Model 2790; value is a
                             resistance
Inspect Data for Pass/Fail – Continue if pass, take appropriate action if fail
Send 2790 ("ROUT:MULT:OPEN (@101,102)") ' Disconnect Shunt Bar A from I-source and DMM
Send 2790 ("SOUR:CURR 0.001, (@127)") ' Set current source level to 1 mA for dry circuit
                                         measurement
Send 2790 ("ROUT:MULT:CLOS (@104,105,124)") ' Connect Shunt Bar B to Current Source and DMM; enable
                                             dry circuit
Send 2790 ("ROUT:MULT:OPEN (@106)") ' Disconnect internal shunt from Shunt Bar B
Send 2790 ("READ?") ' Initialize 2790 and ask for data (triggers a measurement)
Send 2790 ("ROUT:MULT:CLOS (@106)") ' Reconnect internal shunt across Shunt Bar A
Enter 2700 (Data String) ' Enter data into PC from Model 2790; value is a
                             resistance
Inspect Data for Pass/Fail – Continue if pass, take appropriate action if fail
Send 2790 ("ROUT:MULT:OPEN (@121,104,105,117,118,124)")
                               ' Open I-source and disconnect Shunt Bar B from DMM;
                               disable dry circuit

```

Configure and perform Bridgewire tests

Note: Test current verified prior to first bridgewire test. At end of test the internal shunts are left connected to the DUT. Use ROUT:OPEN:ALL if going to disconnect DUT from test system.

```

Send 2790 ("ROUT:MULT:CLOS (@103,106)") ' Connect internal shunts across DUT
Send 2790 ("ROUT:MULT:OPEN (@122)") ' Select I-source; default setting
Send 2790 ("SOUR:CURR 0.05, (@127)") ' Set Current Source level to 50 mA
Send 2790 ("CALC1:STAT OFF") ' Disable any math functions
Send 2790 ("SENS:FUNC 'VOLT'") ' Set DMM to DC Volts
Send 2790 ("SENS:VOLT:RANG 0.1") ' Set voltage range to 100 mV
Send 2790 ("SENS:VOLT:NPLC 1") ' Set integration time to 1 power line cycle
Send 2790 ("ROUT:MULT:CLOS (@101,102,118,125,121)")
                               ' Connect Bridgewire A to Current Source and I-source
                               sense resistor to DMM
Send 2790 ("ROUT:MULT:OPEN (@103)") ' Disconnect internal shunt from Bridgewire A
Send 2790 ("READ?") ' Initialize 2790 and ask for data (triggers a measurement)
Send 2790 ("ROUT:MULT:CLOS (@103)") ' Reconnect internal shunt across Bridgewire A
Enter 2700 (Data String) ' Enter data into PC from Model 2790; reading is a voltage
                             equal in value to test current
Inspect Data for Pass/Fail – Continue if pass, take appropriate action if fail
Send 2790 ("ROUT:MULT:OPEN (@125)") ' Disconnect I-source sense resistor from DMM

```

```

Send 2790 ("CALC1:FORM S1I")           ' Use low ohms (source I measure V) math function to
                                        calculate resistance
Send 2790 ("CALC1:STAT ON")           ' Enable the math function
Send 2790 ("ROUT:MULT:CLOS (@117)")   ' Connect Bridgewire A to DMM
Send 2790 ("ROUT:MULT:OPEN (@103)")   ' Disconnect internal shunt from Bridgewire A
Send 2790 ("READ?")                   ' Initialize 2790 and ask for data (triggers a measurement)
Send 2790 ("ROUT:MULT:CLOS (@103)")   ' Reconnect internal shunt across Bridgewire A
Enter 2700 (Data String)               ' Enter data into PC from Model 2790; value is a
                                        resistance

Inspect Data for Pass/Fail – Continue if pass, take appropriate action if fail
Send 2790 ("ROUT:MULT:OPEN (@101,102)") ' Disconnect Bridgewire A from I-source and DMM
Send 2790 ("ROUT:MULT:CLOS (@104,105)") ' Connect Bridgewire B to Current Source and I-Source and DMM
Send 2790 ("ROUT:MULT:OPEN (@106)")   ' Disconnect internal shunt from Bridgewire B
Send 2790 ("READ?")                   ' Initialize 2790 and ask for data (triggers a measurement)
Send 2790 ("ROUT:MULT:CLOS (@106)")   ' Connect internal shunt across Shunt Bar A
Enter 2700 (Data String)               ' Enter data into PC from Model 2790; value is a
                                        resistance

Inspect Data for Pass/Fail – Continue if pass, take appropriate action if fail
Send 2790 ("ROUT:MULT:OPEN (@121,104,105,117,118)") '
                                        ' Open I-source and disconnect Bridgewire B from DMM

```

Configure and perform Insulation Resistance (HIPOT) tests

Note: Test voltage verified prior to first Insulation Resistance test. At end of test the internal shunts are left connected to the DUT. Use ROUT:OPEN:ALL if going to disconnect DUT from test system. Also, selecting SIVohms math function automatically sets the measurement function to DC Volts and measurement range to 10V.

```

Send 2790 ("ROUT:MULT:CLOS (@103,106)") ' Connect internal shunts across DUT
Send 2790 ("SOUR:VOLT 500, (@128)")    ' Set Voltage Source level to 500 V
Wait 250 ms for V-source to settle     ' Settling time for 50V to 500V transition
Send 2790 ("CALC1:STAT OFF")           ' Disable any math functions
Send 2790 ("SENS:FUNC 'VOLT'")         ' Set DMM to DC Volts
Send 2790 ("SENS:VOLT:RANG 1000")     ' Set voltage range to 1000 V
Send 2790 ("SENS:VOLT:NPLC 1")         ' Set integration time to 1 power line cycle
Send 2790 ("ROUT:MULT:CLOS (@122,113,118,123,121)") '
                                        ' Select V-source and connect DMM across it; connection to
                                        V-source LO is made through I-V converter
Wait approximately 50ms for V-source to settle ' Settling time for step change in load
Send 2790 ("READ?")                   ' Initialize 2790 and ask for data (triggers a measurement)
Enter 2700 (Data String)               ' Enter data into PC from Model 2790; reading is V-source
                                        open circuit voltage (input resistance of DMM on 1000 V
                                        range is 10 MΩ)

Inspect Data for Pass/Fail – Continue if pass, take appropriate action if fail
Send 2790 ("ROUT:MULT:OPEN (@121,122,113)") ' Open 122 to deselect V-source and discharge module; other
                                        channels disconnect V-source from DMM
Send 2790 ("CALC1:FORM S1V")           ' Use high ohms (source V measure I) math function to
                                        calculate resistance
Send 2790 ("CALC1:STAT ON")           ' Enable the math function
Send 2790 ("TRIG:DEL 2")               ' Set nominal 2 sec soak time from when 2790 is
                                        initialized until measurement is made
Send 2790 ("ROUT:MULT:CLOS (@101,108,116,122,121)") '
                                        ' Connect Bridgewire A HI to V-source and Housing LO to
                                        I-V converter; connect I-V converter output to DMM
Send 2790 ("READ?")                   ' Initialize 2790 and ask for data (triggers a measurement);
                                        V-source settles during soak time
Enter 2700 (Data String)               ' Enter data into PC from Model 2790; value is a
                                        resistance

Inspect Data for Pass/Fail – Continue if pass, take appropriate action if fail
Send 2790 ("ROUT:MULT:OPEN (@121,122,101)") ' Discharge module and cables; disconnect V-source and
                                        Bridgewire A HI from test circuit
Send 2790 ("ROUT:MULT:CLOS (@104,122,121)") ' Select V-source; connect V-source and Bridgewire B HI
                                        to test circuit
Send 2790 ("READ?")                   ' Initialize 2790 and ask for data (triggers a measurement);
                                        V-source settles during soak time
Enter 2700 (Data String)               ' Enter data into PC from Model 2790; value is a
                                        resistance

Inspect Data for Pass/Fail – Continue if pass, take appropriate action if fail
Send 2790 ("ROUT:MULT:OPEN (@121,122,104,108,116,118)") '
                                        ' Discharge module; disconnect V-source, Bridgewire B HI,
                                        I-V converter and DMM from test circuit

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Running the Tests

Performing the tests in the order presented in the “Basic Programming Guidelines” section is one possible approach to testing a dual inflator air bag module. As previously mentioned, the shunt bar tests are often performed multiple times to ensure that the shunts are functional and properly connected. The example code tries to show all of the various measurement capabilities that are discussed in this note, but the need to use any of these features depends on the specific application and test requirements. The instrument configurations used in the example were chosen so that the rated measurement accuracies of the 7751 module should be achieved rather than for maximum test throughput. Several steps can be taken if test speed is critical and noise immunity or measurement accuracy can be traded off. The integration time for the example measurements is set at 1 PLC (power line cycle), which at 60Hz is 16.7ms. The integration time can be reduced by a factor of 100 to just 0.01 PLC at the cost of reduced immunity to power line frequency noise (see the “Noise” section under “Typical Sources of Error.”) Other steps that can be taken to increase speed include turning off the instrument display and turning off the autozero function. Normally, the Model 2790 periodically measures internal voltages corresponding to offsets and amplifier gains to help maintain stability and accuracy over time and changes in temperature. These internal measurements take time; therefore, turning them off can speed up external measurements. This is an acceptable practice, but the autozeroing function should only be disabled for short periods of time to maintain the rated accuracy of the instrument. Similarly, it takes time to update the display; therefore, turning it off also helps speed up measurements for maximum throughput. The commands for setting the integration time in terms of PLCs are included in the program example. The range of this setting is 0.01 to 60 PLCs at 60Hz power line frequency (50 PLCs at 50Hz). The autozero function can be turned off or on by sending “SYST:AZER:STAT OFF or ON” to the 2790. The display is turned off or on by sending “DISP:ENAB OFF or ON” to the 2790.

Typical Sources of Error

Lead Resistance

Resistance is usually measured using either two-wire or four-wire methods. A common source of error in low resistance measurements when only two test leads are used is the amount of series resistance present in the test leads connected to the device-under-test (DUT). *Figure 7a* illustrates the effect of series resistance when the current source and voltmeter use the same pair of test leads, as for the Contact Verification tests. The main problem with the two-wire method as applied to low resistance measurements is the lead resistance (R_{LEAD}). Since the test current (I_{SOURCE}) causes a small but significant voltage drop across the

lead resistances, the voltage (V_{MEAS}) measured by the meter will not be exactly the same as the voltage (V_R) directly across the test resistance (R_{DUT}), and considerable error can result. This is not a problem for qualitative measurements like the contact verification tests where the object is to distinguish between a “relatively low” resistance and an open circuit. However, this is a problem for the bridgewire and shunt bar tests, where more precise and accurate measurements are required. To eliminate the effects of lead resistance, the current source and voltmeter must be separated and four wires used to connect to the device. *Figure 7b* shows the four-wire measurement configuration used for the bridgewire and shunt bar tests. Due to the very high input impedance of the voltmeter, virtually no current flows through the Sense HI and LO leads and therefore V_{MEAS} equals V_R . Note that four-wire ohms measurements are also possible using just the 2790 DMM, but unlike the 7751 and 7752 modules, the test current is not programmable.

Noise

In a production environment, measurement performance can be compromised by external noise produced by machinery, motors, and even fluorescent lights. This can become a significant problem where low-level measurements are required for a high impedance DUT connected to the test equipment by long cables. Normal-mode noise refers to noise signals that appear between the HI and LO input terminals of an instrument. Careful shielding will reduce normal-mode noise. Using twisted pairs can help reduce noise generated by magnetic coupling. Using twisted pairs within an overall shield is an effective method of reducing normal-mode noise. Power line cycle integration can reduce the effects of periodic noise signals at power line frequencies (or harmonics thereof). When the integration time of the A/D converter is set to an integral number of power line cycles, line frequency noise is averaged out over the integration period, resulting in lower normal-mode noise. Nonperiodic noise or noise at other frequencies is not affected significantly by line cycle integration. In this case, digital filtering that averages multiple measurements can be effective. The Model 2790 offers both line cycle integration and digital filtering for normal-mode noise reduction. In general, long integration times and averaging multiple readings can significantly reduce test system throughput. It is up to the test system designer to make the necessary trade-offs between test system speed, signal noise, and measurement accuracy. Normally, noise shields should be connected to input LO, but in some cases where earth-ground based RFI/EMI interference contributes to the noise, connecting to LO may not be completely effective. In this case, using an overall shield tied to earth-ground may be necessary. Common-mode noise refers to noise signals that occur between input HI and input LO and chassis ground. Common-mode noise can be minimized by connecting all shields and/or grounds to a single point in the test system.

Keithley has determined that one acceptable 2790 system cabling solution is to use Belden #8899 wire to connect the DUT to the switch module. This is a very flexible and durable stranded 18AWG wire with rubber insulation rated for 5kV. The wire bundle should be enclosed in an overall wraparound shield, such as Zippertubing Series ZTZ-* -SH3. The shield should be connected to a safety earth ground. Keithley recommends that users contact The Zippertubing Company for assistance in selecting the appropriate product for their specific applications (301-527-0488, www.zippertubing.com).

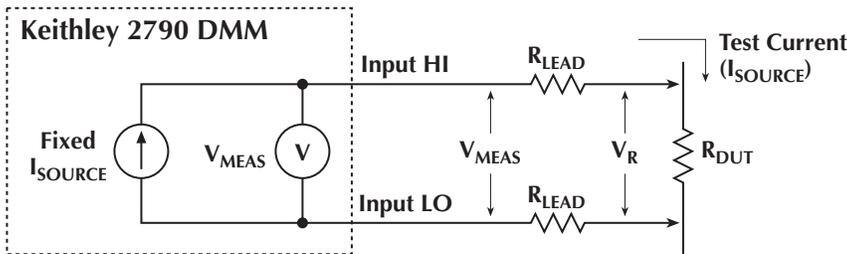
3b. For RS-232 (Serial) Operation:

- PC with available serial port
 - Model 7009-5 Shielded RS-232 Cable (wired as straight-thru cable, not as null modem cable)
4. Custom digital I/O cable for connecting DIO 9-pin male D-sub connector and/or Trigger Link 8-pin female DIN connector of Model 2790 to the component handler
 5. Custom wiring harness for connecting the test equipment to the inflator under test (see “Noise” under “Typical Sources of Error.”)

Equipment List

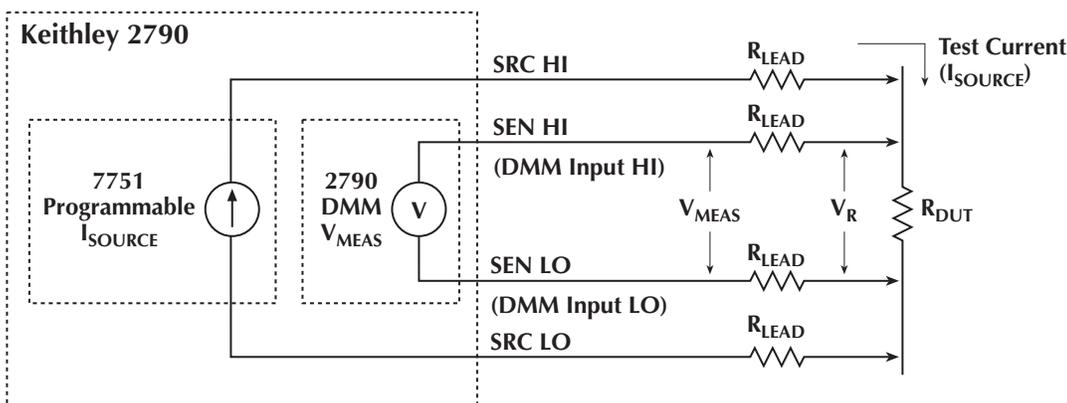
The following equipment is required to assemble the PC controlled air bag inflator test system shown in *Figure 1*.

1. Model 2790 SourceMeter Switch System
 2. One Model 7751 Module
- 3a. For IEEE-488 (GPIB) Operation:
- PC with Model KPCI-488 GPIB computer interface board
 - Model 7007 Double-Shielded GPIB Cable (available in different lengths)



$$R = \frac{V_{\text{MEASURED}}}{I_{\text{SOURCE}}} = R_{\text{DUT}} + (2 \times R_{\text{LEAD}})$$

Figure 7a. 2-Wire Ohms Measurement Using DMM $\Omega 2$ Function



$$R = \frac{V_{\text{MEASURED}}}{I_{\text{SOURCE}}} = \frac{V_R}{I_{\text{SOURCE}}} = R_{\text{DUT}}$$

Figure 7b. 4-Wire Ohms Measurement Using 7751 I-Source and 2790 DMM

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