KEITHLEY

Application Note Series

Number 2266

System Tests With the KPCI-3130 Series Analog Output Card

Introduction

Today, the electronics community is experiencing a migration away from traditional test and measurement philosophies and encompassing a more hybrid approach. Several years ago, if one were required to generate or to measure very precise data points, few solutions were available other than benchtop instrumentation. However, the continued evolution of electronic components has lead to the fabrication of precise voltage sources and high-resolution A/D (analog/digital) and D/A hardware, creating a variety of new solutions.

The ability to generate instrument quality analog voltages is available in the KPCI-3130 Series analog output boards. The KPCI-3130 is designed to the PCI-bus standard and provides a wide feature set that is typically not seen in PC-based plug-in analog output hardware. Two of the most unique characteristics of the board are the 4-wire remote sense feature and the 4-quadrant source/sink operation. The functionality of these features is illustrated in the following test examples.

4-Wire Remote Sense Test Description

The ability to perform 4-wire remote sense operations provides a significant advantage over standard analog output hardware. This feature becomes of critical importance when generating control signals over long distances. Significant voltage drops can occur as the result of cable resistances, device interconnections, and terminations; therefore, the programmed output value may not be the voltage delivered to the device under test (DUT).

Incorporating 4-wire remote sense functionality provides the ability to connect sense leads directly to the input of the DUT. The sense high and low connections allow the card to measure (sense) the actual voltage present at the DUT. The analog output can then be automatically adjusted, transparently to the user, to ensure that the required voltage is supplied, regardless of cable lengths and interconnection losses.

4-Wire Remote Sense Test Procedure

In this test, a known voltage level will be programmed from the KPCI-3130 and connected to the DUT using several different cable lengths. The output voltage will be programmed with ExceLINX™ (Keithley's Excel add-in), and the resistance of the cable will be measured using a Keithley Model 2700 Multimeter/Data Acquisition System that is set to 4-wire ohms mode. For comparison purposes, the voltage at the DUT will also be measured without remote sense (this is typically referred to as 2-wire mode).

The load will be connected to the analog output in 2-wire mode as shown in ***Figure 1*** and then connected in 4-wire mode using the sense line inputs as shown in ***Figure 2***. The OUT0 and GND signals will be connected to pins 1 and 19 respectively, and the S0H and S0L signals will be connected to pins 2 and 20.

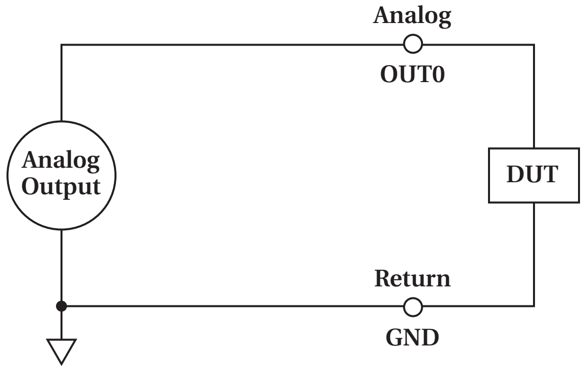

Figure 1. Conventional 2-Wire Analog Output Connections

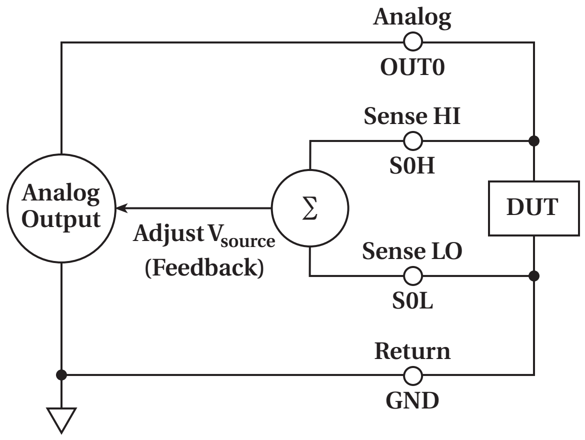

Figure 2. Analog Output with 4-Wire Remote Sense

The data below was obtained using the KPCI-3130's source feature and a Model 2700 Multimeter/Data Acquisition System:

Signal Path (Per lead)	Resistance (Ohms Per lead)	Programmed Value (Volts)	2-Wire Mode Measured Value (Volts w/o sense)	4-Wire Mode Measured Value (Volts w/sense)
10 ft cable	0.5266	8.000	7.999	8.000
100 ft cable	2.5	8.000	7.920	8.000
6 relays, 4 interconnections, 20 ft cable	4.06	8.000	7.360	8.000

The data clearly indicates that cabling and device interconnections can be significant sources of error.

Constant Current Source Test Description

Another unique feature of the KPCI-3130 is its ability to operate in all four voltage/current quadrants (***Figure 3***). Four-quadrant operation is the ability of a device to sink or source any combination of current or voltage. The KPCI-3130 is capable of performing these operations on each of its eight channels simultaneously. Additionally, the robust nature of the analog outputs permits the sinking or sourcing of up to ±10V @ 20mA, without the need for external excitation. This feature is typically only available on benchtop systems.

The following two examples illustrate the process of configuring a constant current supply that will function in quadrants one and three. The key to generating the desired output current is the proper selection of a shunt resistor. This shunt resistor will be placed in series with the load, and the analog output across the shunt will be maintained at a level that will drive the desired current through the load/shunt pair.

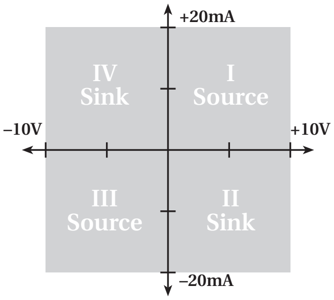

Figure 3. Source/Sink Analog Output Operation

Quadrant 1, Resistive Load Test Procedure

In this example, we will be exploring an application with a test sample (resistive load) that requires a constant current to be applied and controlled, independent of the load. Typically, the load resistance and current requirements will be known and, from this information, we can derive the proper shunt resistor value. This is accomplished by using Ohm's Law and the sum of the series resistance of the load/shunt combination.

This example assumes that the load is 490Ω, the desired current is 20mA, and that the applied voltage will be 10V. From Ohm's Law we can see:

$$V_{ao} = (R_{total} \cdot I) = (R_{shunt} + R_{load}) \cdot 20\text{mA}$$

$$10\text{V} = (R_{shunt} + 490) \cdot 20\text{mA}$$

$$= 20\text{mA} \cdot R_{shunt} + 20\text{mA} \cdot 490$$

Therefore:

$$R_{shunt} = (10 - 20\text{mA} \cdot 490) / 20\text{mA}$$

$$= 10\Omega$$

The analog output voltage will now be a function of the voltage programmed, and sensed, across the shunt resistor. The acceptable shunt voltage levels can once again be determined using Ohm's Law and the specified current:

$$V_{maxshunt} = 20\text{mA} \cdot R_{shunt}$$

$$= 20\text{mA} \cdot 10\Omega$$

$$= 0.2\text{V}$$

Therefore, if 0.2V is programmed, referenced to the shunt resistor, the output across the series resistor network results in 10V @ 20mA. Other current levels can be obtained in the same manner; for example, if a drive current of 10mA were required, the control voltage would be 0.1V.

For this test, connect the load and shunt resistors to the analog output and sense lines as shown in ***Figure 4***. Connect the OUT0 and GND signals to pins 1 and 19 respectively, and connect the S0H and S0L signals to pins 2 and 20.

Note: The shunt resistor must be connected on the ground-side of the load, as shown, if the analog output is to function properly. Failure to do so will result in unpredictable behavior from the analog output circuit and may result in damage to the circuit under test.

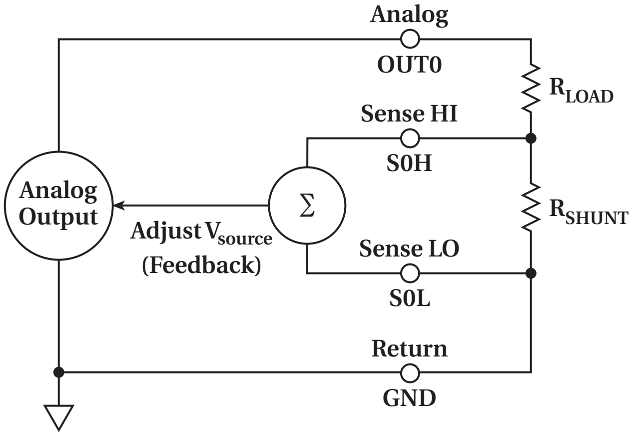

Figure 4. Constant Current Configuration

Quadrant 1 and 3, Battery Charge/Discharge Test Procedure

We will now consider another application where two-quadrant operation is required. This application involves battery charge/discharge cycle testing using a constant current source. The first half of the test requires charging the battery to a specific voltage level (9.6V), followed by discharging the battery to another predetermined level (1.0V).

The charge cycle will occur in quadrant one, where both the voltage and current will be positive. The discharge cycle will then occur in quadrant three, where the voltage and current will be negative. A shunt resistor will be selected, and the voltage drop across it maintained, to limit the charge and discharge currents to a predetermined safe level (10mA in this case). The load resistance of the battery source is quite low; therefore, the calculations that follow assume load resistance to be less than 0.1Ω and negligible. A 10Ω shunt resistor will be used in this case.

The analog output voltage will now be a function of the voltage programmed, and sensed, across the shunt resistor. The acceptable programmed shunt voltage levels can once again be determined using Ohm's Law and the required current:

$$\begin{aligned} V_{maxshunt} &= 10\text{mA} \cdot R_{shunt} \\ &= 10\text{mA} \cdot 10\Omega \\ &= 0.1\text{V} \end{aligned}$$

The shunt circuit analog output can now be set to 0.1V for the charge cycle and –0.1V for the discharge cycle. The actual battery voltage levels can be monitored using an analog input card, such as the KPCI-3101, and the test cycle can be controlled via the user program.

For this test, connect the load and shunt resistor to the analog output and sense lines as shown in ***Figure 5***. Connect the OUT0 and GND signals to pins 1 and 19 respectively, and connect the S0H and S0L signals to pins 2 and 20.

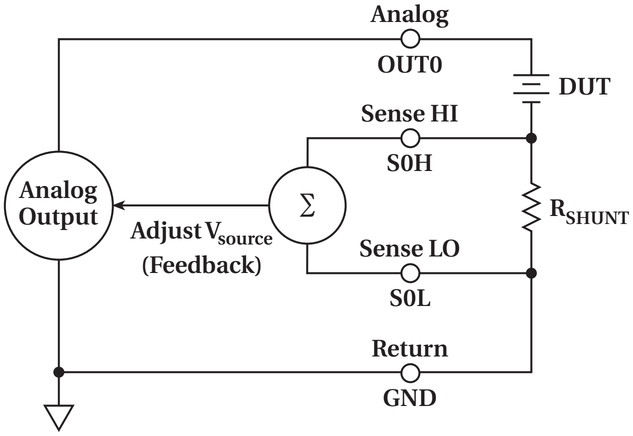

Figure 5. Constant Current Battery Test Configuration

Source/Sink Test Description

Finally, we will discuss the steps necessary to perform a battery charge/discharge cycle test in a constant voltage mode of operation. Unlike the previous example, the KPCI-3130 will both source voltage and sink current.

Quadrant 1 and 2, Battery Charge/Discharge Test Procedure

The first half of the test requires charging the battery to a specific voltage level, followed by discharging the battery to another predetermined level.

The charge cycle will occur in quadrant one, where both the voltage and current will be positive. The discharge cycle will then occur in quadrant two, where the voltage will be positive and the current will be negative. A series resistor will be selected to limit current. The resistor value will be based upon the voltage and current specifications of the DUT. The load resistance of the battery source is quite low; therefore, the calculations that follow assume load resistance to be less than 0.1Ω and negligible.

The analog output voltage will be a function of the voltage programmed, and sensed, across the series combination of the battery and resistor. This example assumes that the maximum charge current is 10mA, the maximum voltage is 9V, and the minimum voltage is 3V. A suitable series resistance can now be selected based upon the test requirements:

$$\begin{aligned} R_{series} &= V_{change} / I_{max} \\ &= (9.0 - 3.0) / 10\text{mA} \\ &= 600\Omega \end{aligned}$$

The analog output can now be set to 9.0V for the charge cycle and 3.0V for the discharge cycle. The actual voltage levels can be monitored using an analog input card, such as the KPCI-3101, and the test cycle can be controlled via the user program.

Note: Unlike the constant current example outlined previously, the exact current level sourced and sunk by the KPCI-3130 will vary with the level of charge of the DUT (a battery in this case). Also, the current flow will be reduced as the potential of the DUT approaches that of the programmed analog output. Therefore, it is critical to select the correct series resistance to limit the maximum current from the analog outputs. Failure to do so can result in damage to the DUT.

For this test, connect the load and shunt resistor to the analog output and sense lines as shown in ***Figure 6***. Connect the OUT0 and GND signals to pins 1 and 19 respectively, and connect the S0H and S0L signals to pins 2 and 20.

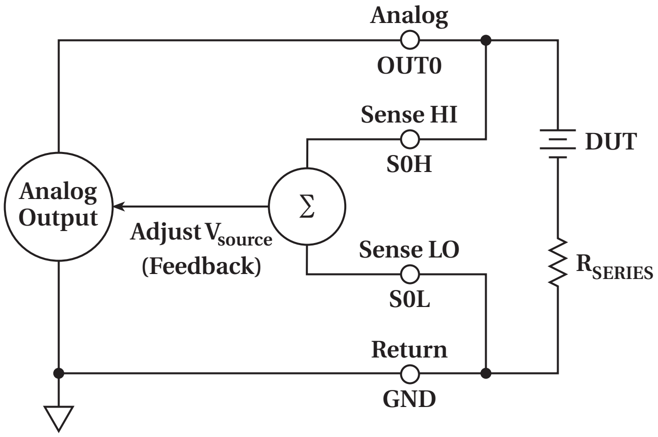

Figure 6. Constant Voltage Battery Test Configuration

Test System Safety

Many electrical test systems or instruments are capable of measuring or sourcing hazardous voltage and power levels. It is also possible, under single fault conditions (e.g., a programming error or an instrument failure), to output hazardous levels even when the system indicates no hazard is present.

These high voltage and power levels make it essential to protect operators from any of these hazards at all times. Protection methods include:

- Design test fixtures to prevent operator contact with any hazardous circuit.
- Make sure the device under test is fully enclosed to protect the operator from any flying debris. For example, capacitors and semiconductor devices can explode if too much voltage or power is applied.
- Double insulate all electrical connections that an operator could touch. Double insulation ensures the operator is still protected, even if one insulation layer fails.
- Use high-reliability, fail-safe interlock switches to disconnect power sources when a test fixture cover is opened.
- Where possible, use automated handlers so operators do not require access to the inside of the test fixture or have a need to open guards.
- Provide proper training to all users of the system so they understand all potential hazards and know how to protect themselves from injury.

It is the responsibility of the test system designers, integrators, and installers to make sure operator and maintenance personnel protection is in place and effective.

Conclusion

The KPCI-3130 Series universal analog output board offers a versatile feature set, qualifying it for consideration in a wide range of control applications. Furthermore, the 4-wire sense function ensures that the DUT is actually being controlled at the voltage level that was programmed; this was evident in the first test example. This 4-wire sense feature is only available from Keithley's analog output cards. Additionally, the four-quadrant operation and the 20mA sink/source current capability can simplify test setup and reduce equipment requirements.

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