Measuring capacitor leakage

In this section:

Introduction 7-1
Equipment required.. 7-1
Set up communication.. 7-2
Device connections 7-2
Measuring leakage current and insulation resistance 7-5

Introduction

This example demonstrates how to use the Model 2657A High Power System SourceMeter® instrument to measure the leakage current and calculate the insulation resistance of a capacitor.

In this example:

1. The capacitor is charged to the desired voltage.
2. The voltage is held across the capacitor for a user-specified amount of time.
3. The current is measured.
4. The Model 2657A discharges the capacitor using the programmed current limit.

Equipment required

Equipment required:

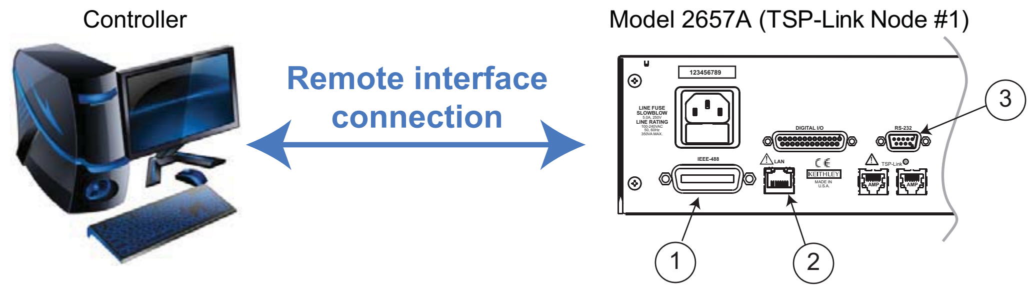
- One Model 2657A High Power System SourceMeter® instrument
- One GPIB or Ethernet cable to connect the Model 2657A to a computer
- One high voltage capacitor enclosed in a safe test fixture, such as the Keithley Instruments Model 8010
- Appropriate cabling to connect the Model 2657A to the test fixture

Set up communication

The communication setup is illustrated in the following figure. This application can be run using any of the supported communication interfaces for the instrument.

For additional detail about remote communications, see "Communications interfaces" in the Model 2657A Reference Manual.

Figure 29: Communication connections



Item	Description	Qty	Notes
1	IEEE-488 connection	1	GPIB. Model 2657A is IEEE Std 488.1 compliant.
2	CA-180-3A LAN connection	1	Model 2657A is LXI version 1.4 Core 2011 compliant. It supports TCP/IP and complies with IEEE Std 802.3 (ethernet). 10 or 100 Mbps.
3	RS-232 connection	1	

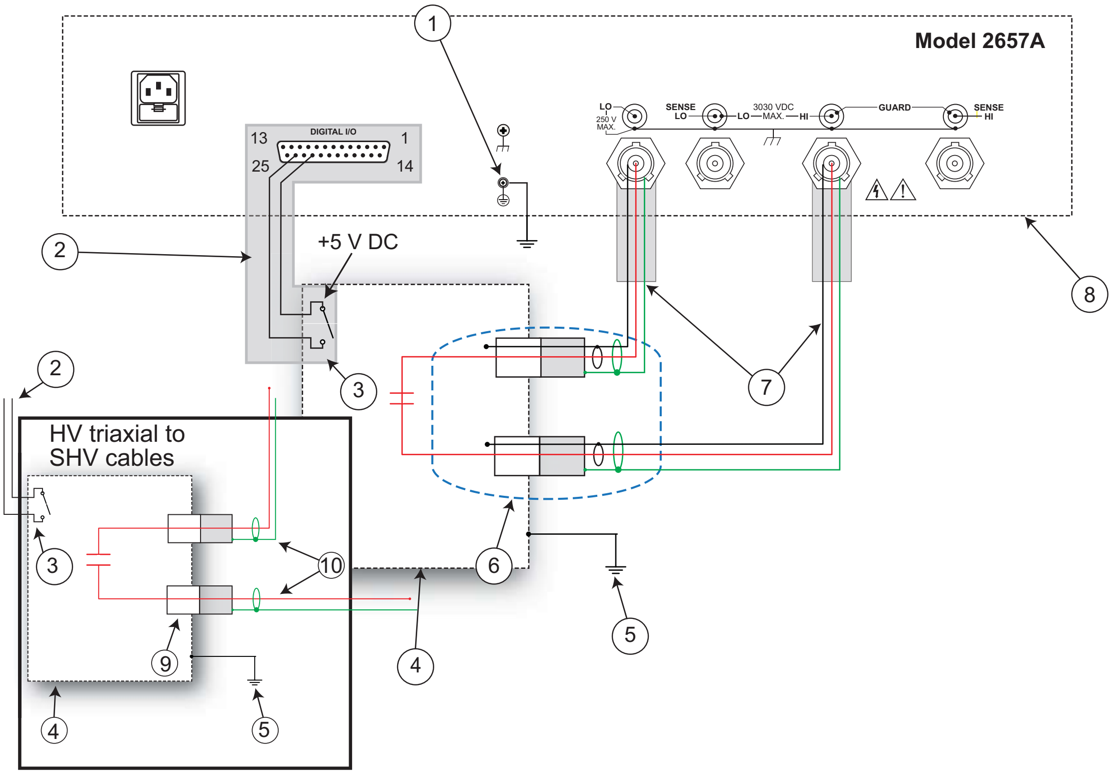
Device connections

Refer to the following figure to connect the diode in a safe test fixture.

See Safe configuration and test setup (on page 2-1) for information on safely connecting the Model 2657A to a device under test (DUT).

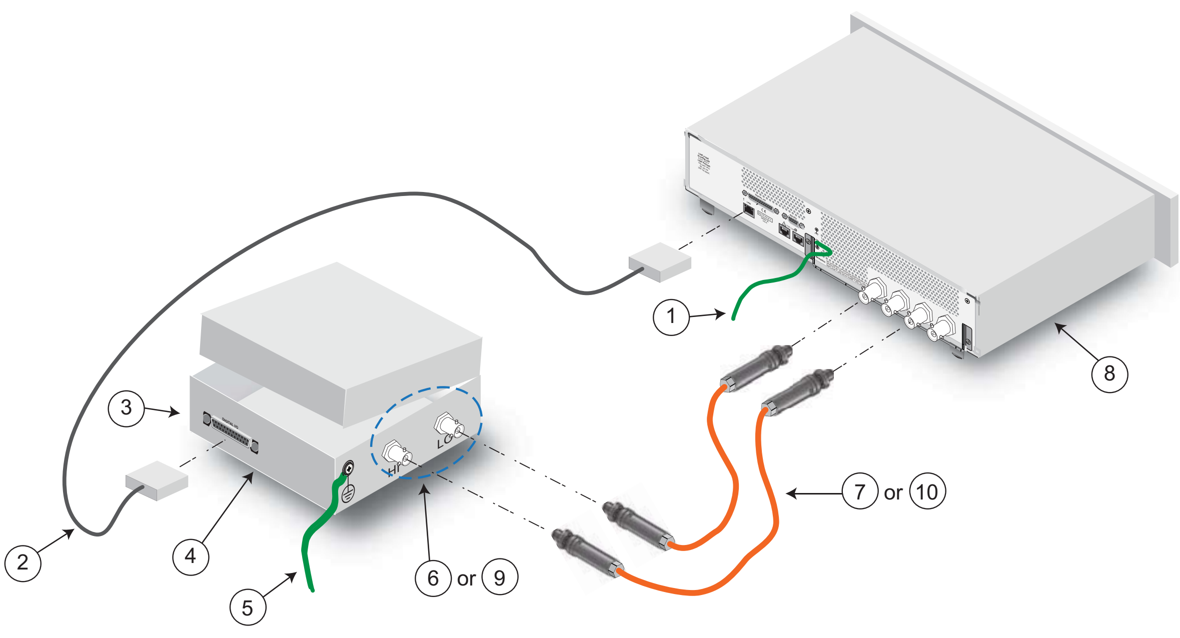
For connections if you are using a Model 8010 High Power Test Fixture, see the Interconnect Reference Guide drawing "Two-terminal axial DUT with a Model 2657A connected" and the Model 8010 User's Manual drawing "Model 2657A connections."

Figure 30: Two-wire capacitor connections



Item	Description	Qty	Notes
1	Model 2657A protective earth (safety ground)	1	Additional connections for redundant protective earth may be required. Keithley Instrument's Model CA-568 is a protective earth (safety ground) cable assembly.
2	Interlock connection	1	Model 2657A digital I/O; pin 24 (INT) and pin 22 (5 VDC) connected to the test fixture lid switch. Keithley Instrument's Model 7709-308 is a 25-pin interlock male connector that can be used for custom connections. Interlock switch is shown in the disengaged (lid open) position.
3	Test fixture interlock switch connection	1	
4	Interlocked metal safety enclosure	1	A safety enclosure with an interlock that has a normally-open (NO) switch.
5	Test fixture protective earth (safety ground)	1	Additional connections for redundant grounds may be required for specific test setups.
6	Model HV-CA-571-3 High-Voltage Triaxial Panel-Mount Connector to Unterminated Cable Assembly	2	See Using high-voltage triaxial connectors (on page 2-7).
7	Model HV-CA-554 High-Voltage Triaxial Cable	4	
8	Model 2657A	1	
9	Panel-mount SHV connectors	2	Customer-supplied.
10	Model SHV-CA-553 High-Voltage Triaxial to SHV Cable	2	

Figure 31: Two-wire capacitor physical connections



Measuring leakage current and insulation resistance

NOTE

The example code is designed to be run from Test Script Builder or TSB Embedded. It can also be run from other programming environments, such as Microsoft® Visual Studio® or National Instruments LabVIEW™. However, you may need to make changes to the example code to use other programming environments.

This example demonstrates a simple method for measuring the leakage current and insulation resistance of a capacitor. This example uses a TSP script to perform the measurement. The script includes two separate functions for configuring the System SourceMeter Instrument and returning the raw current and voltage readings from the reading buffer.

The script is written using TSP functions rather than as a single block of inline code. TSP functions are similar to functions in other programming languages, such as Microsoft® Visual C® or Visual Basic®. They must be called before the code in them is executed. Because of this, running the script alone will not execute the test. To execute the test, you need to run the script to load the functions into test script memory. You then call the functions.

Refer to the documentation for Test Script Builder or TSB Embedded for directions on how to run scripts and enter commands using the instrument console.

Example code

```
function runCapLeak(testV, iLimit, measRange, numReadings, soakTime, numNPLC)

   --Initialize SMU.
   reset()
   errorqueue.clear()
   status.reset()

   --Configure reading buffers.
   smua.nvbuffer1.clear()
   smua.nvbuffer1.appendmode = 0
   smua.nvbuffer1.collecttimestamps = 1
   smua.nvbuffer1.collectsourcevalues = 0

   smua.nvbuffer2.clear()
   smua.nvbuffer2.appendmode = 0
   smua.nvbuffer2.collecttimestamps = 1
   smua.nvbuffer2.collectsourcevalues = 0

   --Configure source function.
   smua.source.func = smua.OUTPUT_DCVOLTS
   smua.source.levelv = testV
   smua.source.limiti = iLimit
```

```
   --[[
   Configure measurement parameters. Each call of the measurement function
   will result in the number of readings specified by smua.measure.count.
   The time specified by smua.measure.delay is enforced before any
   measurements are made.
   --]]
   smua.measure.autozero = smua.AUTOZERO_ONCE
   smua.measure.rangei = measRange
   smua.measure.count = numReadings
   smua.measure.nplc = numNPLC
   smua.measure.delay = soakTime

  --[[
   Run the test.
   Turn on the output. The programmed voltage is output immediately.
   --]]
   smua.source.output = 1
   --[[
   Perform a set of current and voltage measurements. Measure delay is enforced
   before measurements are made.
   --]]
   smua.measure.iv(smua.nvbuffer1, smua.nvbuffer2)
  --[[
   After measurements are complete, return the voltage to 0 V. The rate of
   discharge is limited by programmed current limit.
   --]]
   smua.source.levelv = 0
   --[[
   Wait until the capacitor is fully discharged before turning off
   the output.
   --]]
   delay(soakTime)
   smua.source.output = 0

end
```

```
--[[
   This function prints the raw voltage and current measurements that
   are stored in reading buffers smua.nvbuffer1 and smua.nvbuffer2
--]]

function printData()
   --Retrieve average values of measured current and voltage.
   current_stats = smua.buffer.getstats(smua.nvbuffer1)
   voltage_stats = smua.buffer.getstats(smua.nvbuffer2)
   current_mean = current_stats.mean
   voltage_mean = voltage_stats.mean

   --Calculate the insulation resistance of the capacitor.
   resistance = voltage_mean/current_mean
   --Print the summary of the results to the communication interface.
   print(string.format("Average current: %g", current_mean))
   print(string.format("Average voltage: %g", voltage_mean))
   print(string.format("Insulator Resistance: %g", resistance))

   if  smua.nvbuffer1.n == 0 then
      print("No reading in buffer")
   else
      print("Timestamps\tCurrent\tVoltage")
      for i = 1, smua.nvbuffer1.n do
         print(string.format("%g\t%g\t%g", smua.nvbuffer1.timestamps[i],
          smua.nvbuffer1.readings[i], smua.nvbuffer2.readings[i]))
      end
   end
end
```

Example usage

The functions in this script allow updates to the test parameters without rewriting or re-running the script. To run the test, call the `runCapLeak()` function, passing in the appropriate values for test parameters.

runCapLeak() parameters		
Parameter	**Units**	**Description**
`testV`	volts	The voltage level to test the capacitor with.
`iLimit`	amps	Current limit (compliance) for the test. This limits the rate of charge and discharge of the capacitor
`measRange`	amps	Current measurement range to be used for leakage current measurement.
`numReadings`	not applicable	The number of measurements to make after the soak time elapses; this is the number of readings used to calculate the mean value.
`soakTime`	seconds	Amount of time to apply the voltage before taking a measurement.
`numNPLC`	not applicable	Integration time, specified as the number of power line cycles.

An example of how to call this function is as follows:

```
runCapLeak(2000, 1e-3, 10e-9, 10, 30, 1)
```

This call results in the charge of the capacitor under test to 2000 V. The rate of charge of the capacitor is limited by the 1 mA current limit. The soak time starts after the voltage source is programmed and elapses after 30 seconds. Once the soak time has completed, 10 current measurements are made on the 10 nA range at a 1 PLC integration rate. After all measurements are complete, the voltage source is again programmed to 0 V and the discharge is limited by the 1 mA current limit. The soak time is again enforced to ensure adequate time to discharge the capacitor, then the output is turned off.

You can use the `printData()` function to return the voltage and current measurements and the timestamps that are stored in the buffer. The data is formatted into three columns. To call the `printData()` function, send:

```
printData()
```

An example of the summary of results that print is:

```
Average current: 1.62033e-09
Average voltage: 1999.9
Insulator Resistance: 1.23426e+12
Timestamps Current Voltage
0 1.65E-09 1999.9
0.016698 1.65E-09 1999.9
0.033397 1.63E-09 1999.9
0.050095 1.62E-09 1999.9
0.066793 1.63E-09 1999.9
0.083492 1.64E-09 1999.9
0.10019 1.62E-09 1999.9
0.116889 1.59E-09 1999.9
0.133587 1.57E-09 1999.9
0.150286 1.59E-09 1999.9
```

Sample data is shown in the following graphics. The first graphic shows a typical capacitor leakage curve. The second graphic shows the data that is actually returned by this example. If you were to capture the complete current to time profile of the leakage current, the data shown in the second graphic would occur further out on the x-axis of the first graphic.

Figure 32: Typical capacitor leakage curve

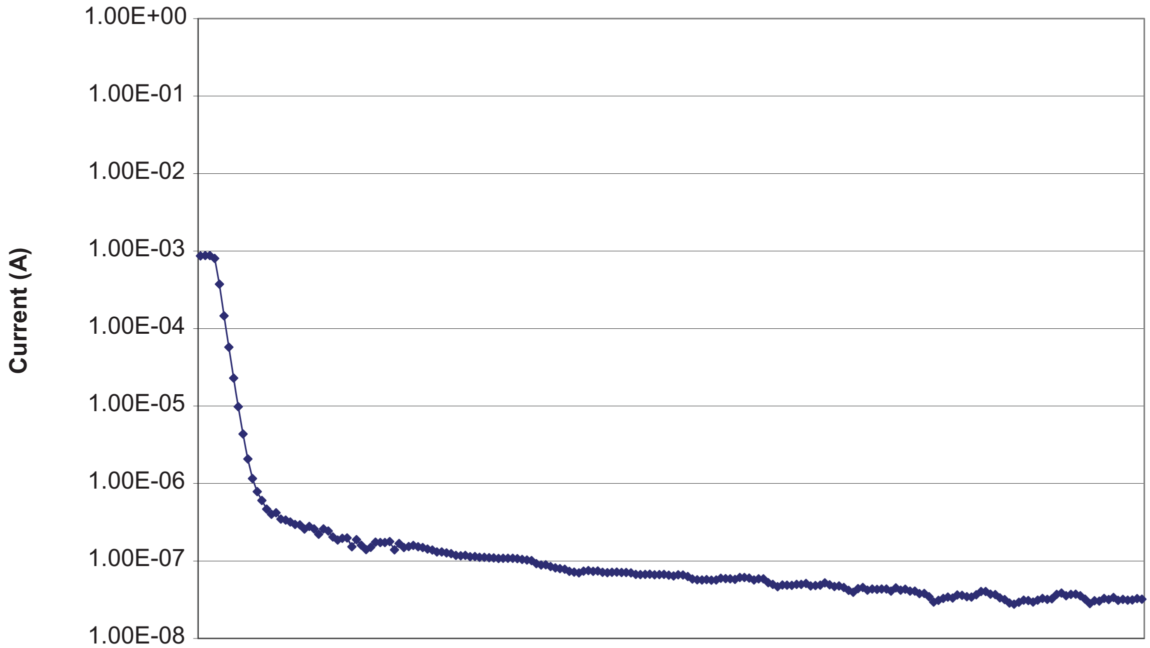
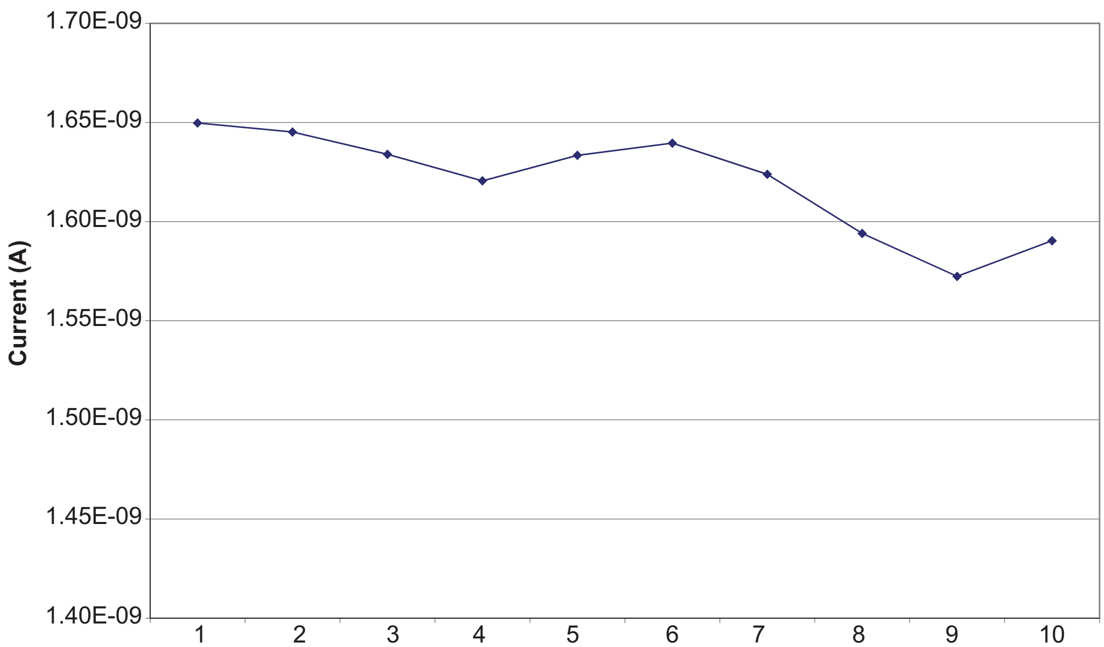


Figure 33: Sample data for capacitor leakage test



NOTE

The Model 2657A voltage source is stable into capacitance values of up to 10 µF typical on the 1500 V and 3000 V ranges. It may also be stable with higher capacitance values. See the latest Model 2657A specifications on the Keithley Instruments website for detail. However, if noisy current measurements or voltage source oscillation occurs, try inserting a resistor or low leakage diode in series with the capacitor. See the application note "Capacitor Leakage Measurements with a Model 6517A Electrometer" on the Keithley Instruments website (ttp://www.keithley.com) for more detail.