Keysight Technologies
Design Tutorial E5061B ENA
Custom Multiport Switch Solution
Using L4491A

Application Note
Table of Contents

1. Introduction .......................................................... 3
2. Resource Requirements ............................................. 3
3. Hardware Configurations ........................................... 4
   3.1 L4491A front panel .............................................. 4
   3.2 System setup ...................................................... 4
   3.3 E5061B network analyzer ........................................ 5
   3.4 L4491A switch platform ......................................... 5
      3.4.1 Switch configuration ........................................ 5
      3.4.2 34945EXT module and distribution board ............ 6
4. Software Installation and Configurations ....................... 7
   4.1 Connection configuration through Keysight connection
       expert using the USB/GPIB interface ......................... 7
   4.2 Connection configuration through Keysight connection
       expert using LAN interface ...................................... 7
   4.3 How to change the GPIB address or IP address .......... 8
5. Switch Box Control Programming Basic ......................... 9
   5.1 Configuration file ............................................... 9
   5.2 Channel assignment and switch control command ....... 10
   5.3 VBA sample code ............................................... 11
   5.4 Operational example with the VBA program .......... 13
1. Introduction

This document describes how to configure a 12-port custom switch box with the Keysight Technologies L4491A RF/Microwave switch platform. It also outlines the basic procedure for operating the custom switch box using the E5061B ENA Series network analyzer.

For a switch box using SP6T switches, the box is designed using a Keysight 50-Ω network analyzer such as the E5061B with Option 235. However, because a 75-Ω multiport switch box solution has wider application, such as for CATV passive component measurements, this document describes how to configure a custom 75-Ω multiport switch box. The custom switch box uses mechanical coaxial switches and can be operated by the E5061B network analyzer via GPIB or LAN.

The custom switch box provides the ability to make a single connection and obtain multiple measurements of multiport devices. This increases throughput by reducing the number of device reconnects that operators need to perform.

Please note that this document provides basic information for designing a custom multiport switch box. For detailed information, refer to the reference resources provided throughout the document.

2. Resource Requirements

<table>
<thead>
<tr>
<th>Product</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>E5061B ENA Series network analyzer with Option 235</td>
<td>1</td>
</tr>
<tr>
<td>L4491A RF Switch Platform</td>
<td>1</td>
</tr>
<tr>
<td>34945EXT module (included in the L4491A chassis)</td>
<td>1</td>
</tr>
<tr>
<td>Terminated SPDT switch (N1810TL-004 or 8762A (low cost))</td>
<td>14</td>
</tr>
<tr>
<td>Terminated SP6T switch (87106A or L7106A (low cost))</td>
<td>4</td>
</tr>
<tr>
<td>Distribution board for SPDT switches (Y1150A)</td>
<td>2</td>
</tr>
<tr>
<td>Distribution board for SP6T switches (Y1151A)</td>
<td>2</td>
</tr>
<tr>
<td>Type N 50-Ω cables (connects the L4491A to the E5061B)</td>
<td>2</td>
</tr>
<tr>
<td>50-Ω N(m) to 75-Ω N(f) minimum loss pad, (Keysight 11852B Option 004), Maximum input power = 250 mW or +24 dBm</td>
<td>12</td>
</tr>
</tbody>
</table>
3. Hardware Configurations

3.1 L4491A front panel

Figure 1 shows an example of the front panel for the 12-port custom switch box. The standard L4491A front panel does not have ports for the reflection, transmission, and test port connectors. These openings must be made by the user to create the custom switch box.

Reflection connector
The reflection connector is a female type-N 50-Ω connector and connects directly to Port 1 of the E5061B using a type-N(m)-to-type-N(m) cable.

Transmission connector
The transmission connector is a female type-N 50-Ω connector and connects directly to Port 2 of the E5061B using a type-N(m)-to-type-N(m) cable.

Test ports (ports 1 to 12)
Ports 1 thru 12 are female type-N 50-Ω connectors and connect to the device under test (DUT). To configure a 75-Ω multiport test set, connect a 50-Ω N(m) to 75-Ω N(f) minimum loss pad to the test port connectors. (If desired, a 50-Ω multiport switch box can be configured by removing the 50-Ω to 75-Ω minimum loss pads in front of test ports on the custom switch box.)

3.2 System setup

Place the L4491A switch platform under the E5061B ENA Series network analyzer. As shown in Figure 2, connect the E5061B and the rear panel of the L4491A using a USB/GPIB or LAN cable.
### 3.3 E5061B network analyzer

**Additional resources**

- Keysight E5061B Network Analyzer, installation guide, document number E5061-90008
- Keysight E5061B Network Analyzer, data sheet, literature number 5990-4392EN

### 3.4 L4491A switch platform

#### 3.4.1 Switch configuration

The 12-port custom switch box consists of fourteen 1 x 2 SPDT switches and four 1 x 6 SP6T switches. Their configuration in the L4491A RF switch platform is shown in Figure 3.

Table 1 shows the connection diagram for the reflection and transmission ports, and test ports 1 thru 12. This configuration supports 12-port full crossbar measurement (12x12 port matrix).

Connect the minimum loss pad (11852B Option 004) to all test ports of the switch box if you are configuring a 75-Ω multiport test set.

The switch and port numbers of RF coaxial switches are shown in Figure 4. These numbers are necessary for the distribution board settings.

#### Table 1. Interconnection between E5061B and Test Ports on L4491A

<table>
<thead>
<tr>
<th>E5061B Port</th>
<th>Test Port on L4491A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port 1 (Reflection port)</td>
<td>Port 1 to Port 11</td>
</tr>
<tr>
<td>Port 2 (Transmission port)</td>
<td>Port 2 to Port 12</td>
</tr>
</tbody>
</table>

**Figure 3. Switch configuration**

**Figure 4. Switch number and switch channel**
3.4.2 34945EXT module and distribution board

Two types of distribution boards are installed on the 34945EXT switch driver module. The SPDT switch is controlled via the Y1150A distribution board and the SP6T switch is controlled via the Y1151A distribution board.

The 34945EXT switch driver module is divided into four banks organized by channel number. (Refer to Section 5.2 “Channel assignment and switch control command.”) Any distribution board may be installed in any bank, and multiple distribution boards of the same type may be installed in the same 34945EXT module.

Additional resources
Keysight 34945A Microwave Switch / Attenuator Driver Module User’s Guide, page 20, document number 34980-90045

An example of an L4491A switch assembly is shown in Figure 5.

Warning: Do not connect a DUT that has DC bias is applied. Use a blocking capacitor to prevent damaging the minimum loss pad.

Additional resources
L4491A switch platform: Keysight L4490A/91A RF Switch Platform, data sheet, literature number 5989-7857EN

8710x Series SP6T switches: Keysight 8710x Series Coaxial Multiport Switches operating and service manual, page 17, document number 87104-90001

Keysight RF and Microwave Switch Selection Guide, literature number 5989-6031EN

N1810 SPDT switches: N1810/1/2 Coaxial Switches, technical overview, literature number 5968-9653E

8710x Series 10x Series SP6T switches: Keysight 8710x Series Coaxial Multiport Switches operating and service manual, page 17, document number 87104-90001

Additional resources
Keysight L4490A/91A RF Switch Platform, data sheet, literature number 5989-7857EN

8710x Series SP6T switches: Keysight 8710x Series Coaxial Multiport Switches operating and service manual, page 17, document number 87104-90001

Keysight RF and Microwave Switch Selection Guide, literature number 5989-6031EN

N1810 SPDT switches: N1810/1/2 Coaxial Switches, technical overview, literature number 5968-9653E

Figure 5. Example of multiport switch assemblies

Figure 6. Configuration of distribution boards on the 34945EXT
4. Software Installation and Configurations

The L4491A is a slave instrument controlled by the E5061B network analyzer. The E5061B has a built-in macro function, allowing a single instruction to substitute for multiple instructions. The E5061B can automatically execute a macro-program containing a series of Visual Basic® for Application (VBA) statements.

Additional resources
Configuring LAN and GPIB interface: Keysight 34945A Microwave Switch / Attenuator Driver Module User’s Guide, page 43, document number 34980-90045

4.1 Connection configuration through Keysight connection expert using the USB/GPIB interface

1. Run Keysight connection expert on the E5061B by selecting the icon in the task tray. If you cannot see the task tray, resize the E5061B graphical user interface (GUI) by selecting “Minimize” from the “Resize” menu on the top right corner on the screen.

2. Connect the E5061B and the L4491A using a USB/GPIB interface such as the 82357B. When configured properly the connection is detected automatically and the L4491A appears on “Instrument I/O on this PC” panel of Keysight connection expert as shown in Figure 8.

3. Set the IP address, gateway, and subnet mask of the L4491A.
   - For the local connection:
     - IP address
     - Set the L4491A’s IP address one unit higher than the E5061B’s IP address.
     - For example, if the IP address of the E5061B is 192.168.0.1 set the L4491A’s IP address to 192.168.0.2.
     - Gateway address.
     - Enter the same value as the E5061B’s gateway.
     - Subnet mask.
     - Enter the same value as the E5061B’s gateway.

4. For the network connection
   Use the IP address, gateway, and subnet mask assigned by your IT department.

4.2 Connection configuration through Keysight connection expert using LAN interface

1. Run Keysight connection expert on the E5061B by selecting the icon on the task tray.

2. Connect the E5061B to the L4491A using a LAN cable. When connecting the E5061B directly to the L4491A, use the LAN cross-over cable (p/n 5061-0701) provided with the L4491A instrument. For network configurations that include a LAN switch or router between the E5061B and the L4491A, a standard LAN cable can be used.

3. Set the IP address, gateway, and subnet mask of the L4491A.
   For the local connection:
   - IP address
   - Set the L4491A’s IP address one unit higher than the E5061B’s IP address.
     For example, if the IP address of the E5061B is 192.168.0.1 set the L4491A’s IP address to 192.168.0.2.
   - Gateway address.
     Enter the same value as the E5061B’s gateway.
   - Subnet mask.
     Enter the same value as the E5061B’s gateway.

4. For the network connection
   Use the IP address, gateway, and subnet mask assigned by your IT department.
4.3 How to change the GPIB address or IP address

1. Run Keysight connection expert.

2. Select “Keysight L4491A” then right click “Access Instrument Web Interface” on the Keysight connection expert drop-down window.

3. When the L4491A LXI menu appears, select “View & Modify Configuration”.

4. When the “Current Configuration of L4491A RF Switch Platform” menu appears, select “Modify Configuration”.

5. When the “Configuring your L4491A RF Switch Platform” menu appears, input the IP address or GPIB address.

6. To store the new address information, select “Save”.

Figure 9. Path to “Access Instrument Web Interface”

Figure 10. Access to “View & Modify Configuration”

Figure 11. Entry screen for new IP or GPIB address
5. Switch Box Control Programming Basic

5.1 Configuration file

The configuration of the L4491A custom switch box is defined in a .csv-format configuration file similar to the one shown in Figure 12.

1. Enter the GPIB or IP address of the L4491A unit. For a LAN cable connection, use the LAN VISA address of the L4491A such as “TCPIPO::192.168.0.2::inst0::INS TR”. Refer to Section 4 for details on how to verify the L4491A’s instrument address.

2. Enter switch types, and bank and slot numbers for each switch. The L4491A and 34945EXT number is always “1”. (Refer to Keysight 34945A Microwave Switch / Attenuator Driver Module, user’s guide, document number 34980-90045 for bank, slot, and channel numbering rules.)

3. Enter the port number definition of the RF switches appropriate for each switch type.

4. Enter switch configurations for Port 1 (reflection port) and Port 2 (transmission port).

Figure 12. Example of a .csv-format configuration file
5.2 Channel assignment and switch control command

RF switches are controlled by channel syntax as shown in Figure 13.

The channel syntax is defined by a four digit number and decides the contact path of the RF switches.

Channel Syntax = <Slot #><Ext #><Ch #>

Slot #: always 1.
Ext #: always 1.
Ch #: see Table 2.

The lower two digits of the channel syntax are associated with each bank on the 34945EXT. Refer to Table 2.

The Table 3 describes the default settings for the channel syntax of the 18 RF switches. The channel syntax values are set in the initialization process of the switch control program.

For example, if you assign Test Port 3 as the reflection port (E5061B Port 1), send the following commands:

"ROUT:CLOS(@1126)"
"ROUT:CLOS(@1143)"
"ROUT:CLOS(@1113)"

Table 2. Lower two digits of the channel syntax

<table>
<thead>
<tr>
<th>Bank</th>
<th>Channels (lower)</th>
<th>Channels (upper)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank 1</td>
<td>01 - 08</td>
<td>11 - 18</td>
</tr>
<tr>
<td>Bank 2</td>
<td>21 - 28</td>
<td>31 - 38</td>
</tr>
<tr>
<td>Bank 3</td>
<td>41 - 48</td>
<td>51 - 58</td>
</tr>
<tr>
<td>Bank 4</td>
<td>61 - 68</td>
<td>71 - 78</td>
</tr>
</tbody>
</table>

Table 3. Default channel syntax settings

<table>
<thead>
<tr>
<th>SW#</th>
<th>Channel syntax</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>@1111</td>
<td>&quot;ROUT:CLOS (@1111)&quot;</td>
</tr>
<tr>
<td>2</td>
<td>@1102</td>
<td>&quot;ROUT:CLOS (@1102)&quot;</td>
</tr>
<tr>
<td>3</td>
<td>@1103</td>
<td>&quot;ROUT:CLOS (@1103)&quot;</td>
</tr>
<tr>
<td>4</td>
<td>@1104</td>
<td>&quot;ROUT:CLOS (@1104)&quot;</td>
</tr>
<tr>
<td>5</td>
<td>@1105</td>
<td>&quot;ROUT:CLOS (@1105)&quot;</td>
</tr>
<tr>
<td>6</td>
<td>@1106</td>
<td>&quot;ROUT:CLOS (@1106)&quot;</td>
</tr>
<tr>
<td>7</td>
<td>@1117</td>
<td>&quot;ROUT:CLOS (@1117)&quot;</td>
</tr>
<tr>
<td>8</td>
<td>@1131</td>
<td>&quot;ROUT:CLOS (@1131)&quot;</td>
</tr>
<tr>
<td>9</td>
<td>@1132</td>
<td>&quot;ROUT:CLOS (@1132)&quot;</td>
</tr>
<tr>
<td>10</td>
<td>@1133</td>
<td>&quot;ROUT:CLOS (@1133)&quot;</td>
</tr>
<tr>
<td>11</td>
<td>@1134</td>
<td>&quot;ROUT:CLOS (@1134)&quot;</td>
</tr>
<tr>
<td>12</td>
<td>@1125</td>
<td>&quot;ROUT:CLOS (@1125)&quot;</td>
</tr>
<tr>
<td>13</td>
<td>@1136</td>
<td>&quot;ROUT:CLOS (@1136)&quot;</td>
</tr>
<tr>
<td>14</td>
<td>@1127</td>
<td>&quot;ROUT:CLOS (@1127)&quot;</td>
</tr>
<tr>
<td>15</td>
<td>@1141</td>
<td>&quot;ROUT:CLOS (@1141)&quot;</td>
</tr>
<tr>
<td>16</td>
<td>@1156</td>
<td>&quot;ROUT:CLOS (@1156)&quot;</td>
</tr>
<tr>
<td>17</td>
<td>@1161</td>
<td>&quot;ROUT:CLOS (@1161)&quot;</td>
</tr>
<tr>
<td>18</td>
<td>@1176</td>
<td>&quot;ROUT:CLOS (@1176)&quot;</td>
</tr>
</tbody>
</table>
5.3 VBA sample code


**frmMain ->**

**UserForm_Initialize()**
This sub-routine initializes the VBA UI (refer to Figure 15). The VBA macro loads the switch port names which are displayed in the list box from the configuration file.

**SwitchControl -> Set IO**
This subroutine initializes the VISA COM I/O.

```vba
Option Explicit
Private Sub UserForm_Initialize()

On Error GoTo ErrHandle
    'Read configuration file.
    Call ReadSWConfig("D:\VBA\SW_Config_E5061B.csv")
    'Initialize VISA COM ID.
    Call SetIO(SWBoxInfo.BoxAddr)
    'Initialize switch settings
    Call InitSWSetting
    'Initialize list box settings.
    ListBox

Exit Sub

ErrHandle:
    MsgBox Err.Description, , "Error@UserFormInitialize"
    Err.Clear

End Sub
```

```vba
Public Sub SetIO(IOaddress1)

On Error GoTo ErrHandle
    'Initialize the VISA COM IO for communication
    Dim io_mgr As VisaComLib.ResourceManager

    If IOaddress1 <> "None" Then
        'Instantiate the Global Resource Manager
        Set io_mgr = New VisaComLib.ResourceManager
        Set SWBox1 = New VisaComLib.FormattedIO488
        Set SWBox1.IO = io_mgr.Open(IOaddress1)
    '----------------------------------------------
    'Set the drive current source to internal.
    SWBox1.WriteString("ROUT:RMOD:DRIV:SOUR INT,(@1000)")

    End If

Exit Sub

ErrHandle:
    MsgBox Err.Description, vbExclamation, "Error@SetIO"

End Sub
```
SwitchControl -> SetSwitch
This subroutine sends switch setting SCPI commands (ROUT:CLOS) by reading the connection test port number from the VBA UI (refer to Figure 15).

```
Sub SetSwitch(swState As Integer)
    Dim ipt As Integer, sw_No1 As Integer, sw_No2 As Integer, sw_No3 As Integer
    Dim ipt As Integer, istate As Integer
    Dim swchT As String, swchM As String, swchB As String
    Dim tmp5 As String, tmp1 As String

    For ipt = 1 To 2
        '---Top Switches------------------------
        tmp1 = swState(swState(ipt)).sw_top(ipt)
        If tmp1 <> "None" Then
            vtmp = Split(tmp1, ".")
            sw_No1 = CInt(Mid(vtmp(0), 3, Len(vtmp(0)) - 2))
            istate = vtmp(1)
            Get channel syntax.
            swchT = sw_addr(sw_No1, istate)
        End If

        '---Middle Switches-----------------------
        tmp1 = swState(swState(ipt)).sw_mid(ipt)
        If tmp1 <> "None" Then
            vtmp = Split(tmp1, ".")
            sw_No2 = CInt(Mid(vtmp(0), 3, Len(vtmp(0)) - 2))
            istate = vtmp(1)
            Get channel syntax.
            swchM = sw_addr(sw_No2, istate)
        End If

        '---Bottom Switches------------------------
        tmp1 = swState(swState(ipt)).sw_btm(ipt)
        If tmp1 <> "None" Then
            vtmp = Split(tmp1, ".")
            sw_No3 = CInt(Mid(vtmp(0), 3, Len(vtmp(0)) - 2))
            istate = vtmp(1)
            Get channel syntax.
            swchB = sw_addr(sw_No3, istate)
        End If

        '---SW Switching-------------------------
        If swchT <> "" Then
            "Switching control for top switches.
            SWBox1.WriteLine("ROUT:CLOS (@) + &swchT + ")"
        End If
        If swchM <> "" Then
            "Switching control for middle switches.
            SWBox1.WriteLine("ROUT:CLOS (@) + &swchM + ")"
        End If
        If swchB <> "" Then
            "Switching control for bottom switches.
            SWBox1.WriteLine("ROUT:CLOS (@) + &swchB + ")"
        End If
    Next ipt
End Sub
```
SwitchControl -> SW_addr
This sub-routine calculates the channel syntax of the required switch setting. The routine is called from the SetSwitch() sub-routine.

Private Function SW_addr(SW As Integer, iState As Integer) As String
    '34945EXT @11"
    'Bank1 1 - 6, 11 - 18
    'Bank2 21 - 28, 31 - 38
    'Bank3 41 - 48, 51 - 58
    'Bank4 61 - 68, 71 - 78
    Dim iTmp As Integer, iTmp0 As Integer, iTmp1 As Integer, iTmp2 As Integer
    iTmp0 = SWProp(ISW).I34945EXT
    iTmp = 2 * (SWProp(ISW),Bank - 1)
    Select Case SWProp(ISW),SWtype
        Case "SP4T"
            iTmp1 = iTmp + SWProp(ISW),Slot - 1
            iTmp2 = vSP4T(iState)
        Case "SP6T"
            iTmp1 = iTmp + SWProp(ISW),Slot
            iTmp2 = vSP6T(iState)
        Case "SPDT"
            iTmp1 = 2 * (SWProp(ISW),Bank - 1) + vSPDT(iState)
            iTmp2 = SWProp(ISW),Slot
    End Select
    SW_addr = "*1" + CStr(iTmp0) + CStr(iTmp1) + CStr(iTmp2)
End Function

5.4 Operational example with the VBA program

When you load the VBA project and run the macro using the [Macro Run] hard key, a user-defined form appears (refer to Figure 15).

You can select the test ports for the reflection and transmission ports.
1. Select the test port for the reflection port.
2. Select the test port for the transmission port.
3. Click “Set” button to change the switch connection.

Figure 15. Multiport control program
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