Application Note 332-1

HEWLETT PACKARD

Switching

Novel combinations of microwave switches and step attenuators for programming applications

Abstract

HP introduced the "edge-line" transmission technology in the late 1960s to simplify and improve the design of coaxial step attenuators and coaxial switches. Now, by using the basic structure of the 3- and 4-step attenuators, HP engineers have devised a number of custom combinations of switches and step attenuation that are quite novel. The design engineer/reader is challenged to apply these capabilities to their current problems.

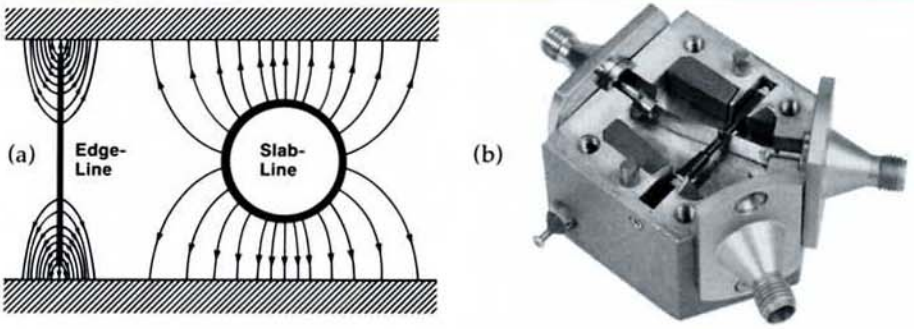


Figure 1. The "edge-line" transmission line concept (a) uses a flat center-conductor perpendicular to two ground planes which concentrates the field pattern at its edges. This allows a flexible "flipper" blade in the HP 8761A/B Coaxial Switch (b) to contact either output connector port.

The Edge-Line Structure

In 1967, as the HP 8410 Network Analyzer was capturing the imagination of that generation's designers, a small team of HP microwave engineers were working on the component underpinnings of that new technology. They were designing a series of signal separation and switching boxes for input to the Network Analyzer. Key to the proper performance of some of those components was a new switch structure using a strip transmission line configuration called edge-line. It was called edge-line because it was composed of a strip transmission line, standing on edge between two ground planes. (See Figure 1.)

The beauty of this configuration was that the strips could be made thin and flexible, thereby permitting bending without affecting the impedance along the line. One product resulting was the HP 8761A Switch, shown in an open view in Figure 1, and operating with magnetically-latching solenoids for programmable control. In the same figure, a "slab-line" field configuration with round center conductors is compared with the perpendicular strip or edge-line.

The well-matched electrical performance, excellent repeatability and long-life operation provided by the simple wiping action of the "flipper" blade switch allowed measurement parameters to be obtained without reconnecting the Unit-Under-Test. Soon after, that switch design became the basis of a line of programmable step attenuators of the HP 33300-Series providing 110 dB range with signal performance to 18 GHz.

The 1980s versions of those early switches and step attenuators are typified by the HP 33311 Coaxial Switch, shown cutaway in Figure 2 and the HP 33323K Step Attenuator shown in Figure 3. The HP 33311B/C Switch uses a "see-saw" action to engage and retract 4 plungers with shorting bars which also operate in an edge-line mode. Of particular interest in many applications is the isolation performance of those switches of over 90 dB even to 18 GHz, and more than 50 dB to 26.5 GHz.

Figure 2. Internal view of HP 33311B Switch shows "see-saw" action of shorting bar plungers. Note the two internal 50-ohm terminations on sapphire at the edges.

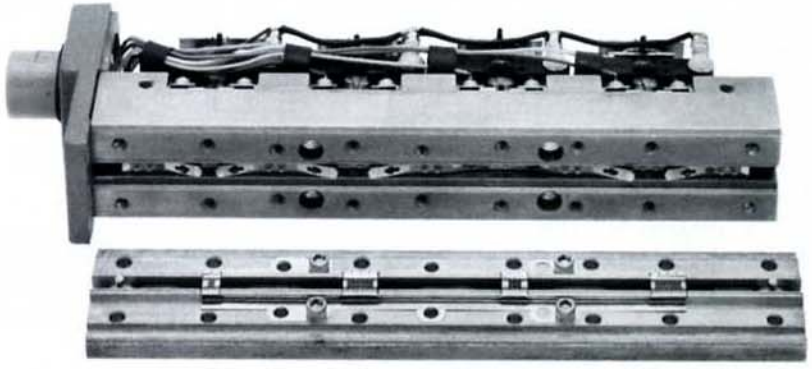


Figure 3. Cutaway view of HP 33323K Step Attenuator shows attenuator pads foreground and switching "flippers" of the edge-line structure.

One of the useful applications of a 4-port variation of that switch (HP 33312B) is in signal transfer switching, as shown in Figure 4. In that case, a device such as a filter or amplifier can be inserted or removed from a signal path. In addition, the 4-port switch can be used as the cross-connection/through-connection switching function required at each intersection of larger full-access matrices. (See Figure 5.) Complete application details of such matrix switching is covered in HP's Application Note 332, "Microwave Switching from SPDT to Full-Access Matrix," Lit. Number 5953-6466.

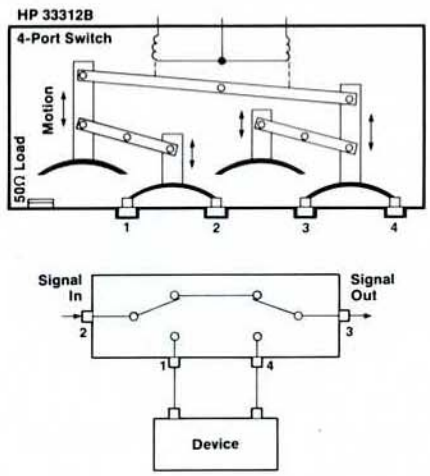


Figure 4. Equivalent transfer switching function of 4-port switch above.

Now comes the interesting part. The programmable step attenuators of the HP 33323-Series basically are internally constructed with 3 or 4 separate transfer switches which cut in or remove separate fixed attenuator pads of 10, 20, and 40 dB values (or 1, 2 and 4 in the 11 dB models). See Figure 6 for a schematic diagram of the internal functions of the 4-step attenuator.

Each transfer function consists of pairs of the previously-mentioned switch "flippers" which move between a through-line with 0 dB loss to the proper fixed pad with flat

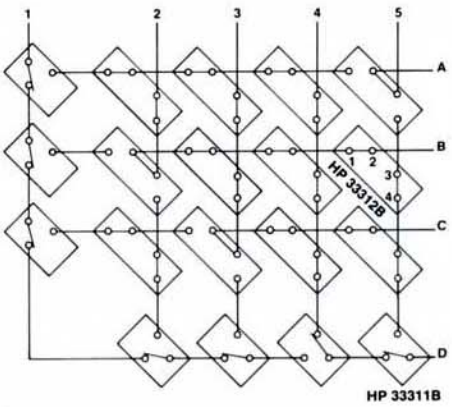


Figure 5. 5 x 4 matrix with connections for 2B, 3C, 4D and 5A, and unneeded intersection switch at 3B and 4C.

loss. Solenoids actuate pairs of push-rods, and are magnetically latched. In addition, tiny glass-rods attached to the moving armature, interrupt coil contacts and cut off the coil power after the latching action has taken place, and thus reduces drive power.

Notice that the fixed attenuator elements are mounted on a separate transmission line structure along the bottom plate, and are designed for best match to permit the entire device to operate to 26.5 GHz. And it is the functionality of those 6 (3-pad) or 8 (4-pad) internal flipper switches which open up some very interesting custom modifications. These have found considerable use inside HP instruments in applications where combined switch functions and attenuation functions are required.

A Single-Pole, Multiple-Throw Switch to 26.5 GHz

The first modification consisted of removing all four attenuator pads from the bottom plate and replacing them with 4 output connectors. For reference, see Figure 7, which shows where the output connectors are installed. As the signal path shows, the input signal port is connected with port 2, while the remaining circuitry to the right side is unused. The transmission-line structure operates well to 26.5 GHz, with some isolation and line-loss limitations. On the other hand, since the switch physical configuration is quite compact, and by proper design, the isolation limitations may be minimized.

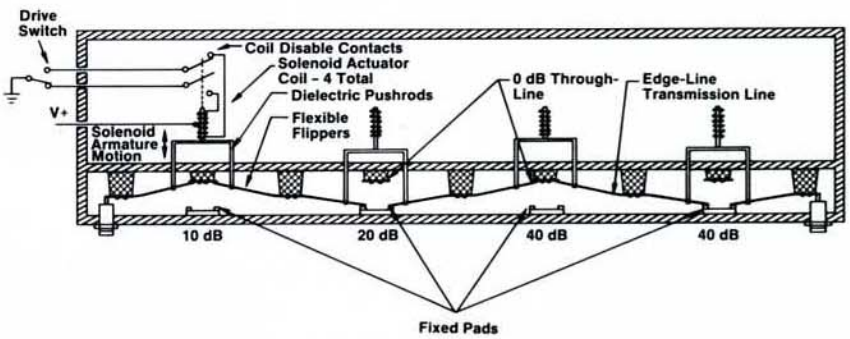


Figure 6. Standard 110 dB Step Attenuator.

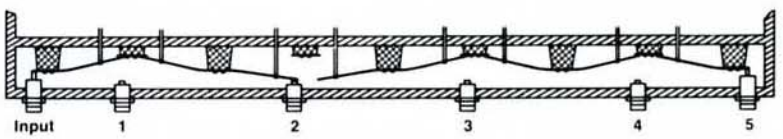
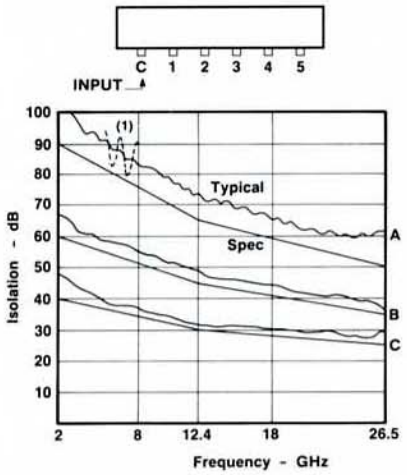


Figure 7. 1-pole, 5-throw Coaxial Switch for 26 GHz operation shown switched to port 2.

Figure 8 shows typical isolation characteristics for the SP5T switch. The important thing to note is that the application can help decide how to implement the switch.



Port Selected	Isolation to Other Ports[1] (See Curves A, B, C Above) 1	2	3	4	5[2]
1	—	A	A	A	B
2	C	—	A	A	B
3	C	C	—	A	B
4	C	C	C	—	B
5[2]	C	C	C	C	—

[1] Ripple varies according to Return Loss of devices connected to ports.

[2] This table shows 5-throw performance. For 3-, 4-, or 6-throw characteristics, the right-hand column of B-curve specs remains as last-port isolation.

Figure 8. Graph shows typical isolation of various ports of a 5-throw switch.

For example, two of these switches are used in a current HP 26.5 GHz synthesizer product to switch between a series of 5 filters, as shown in Figure 9. By arranging for the highest frequencies to have to traverse only the shortest path (the YIG filter for 26.5 GHz), the higher losses getting to the LP filter (which then only passes dc to 2 GHz) are not critical.

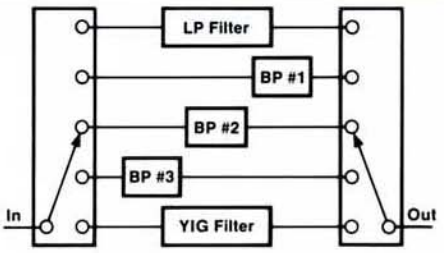


Figure 9. A pair of SP5T selector switches can serve to "transfer" "n" components into a signal path.

Drive cable connectors are available, in either a round-connector configuration (Viking Co.), or with flat ribbon and DIP-type connector for use with printed circuit board wiring.

Switch Function	Viking Connector	16" Ribbon Cable*
SP3T	HP 33323K Opt. K13	HP 33323K Opt. K23
SP4T	HP 33323K Opt. K14	HP 33323K Opt. K24
SP5T	HP 33323K Opt. K15	HP 33323K Opt. K25
SP6T	HP 33323K Opt. K16	HP 33323K Opt. K26

*An 8" ribbon option is also available for tight packaging.

A Double-Transfer Switch

By operating two adjacent solenoids in parallel, two separate transfer switch functions may be configured as shown in Figure 10. In this case, two adjacent coils operate in parallel to cut in or remove each external device from the transmission path. Because of the typical isolation of these switching arrangements, it is recommended that typical isolation requirements of approximately 40 to 50 dB be planned. The situation is somewhat helped by the fact there are two opened-switch points in series with the through-line segment each time the external device is switched in.

Switch Function	Viking Connector	16" Ribbon Cable
Dual-Transfer	HP 33323K Opt. K30	HP 33323K Opt. K40

Adding an SPDT to the Double-Transfer Switch

A custom 5-pad attenuator body permits not only the double transfer as shown in Figure 10, but allows inclusion of an additional SPDT selector switch at one end. This function is shown in Figure 11. Sometimes this can be very efficient if that extra function previously required another SPDT device

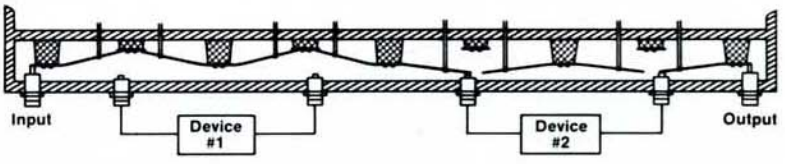


Figure 10. Dual Transfer Switch showing device #2 inserted in signal path.

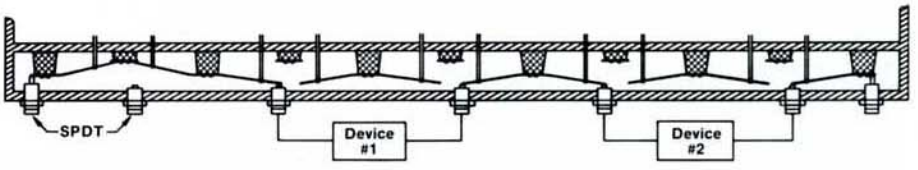


Figure 11. Two transfer switches plus an SPDT, using a custom 5-pad structure.

elsewhere. The end-switch can of course be an SPST function by leaving off one connector.

Switch Function	Viking Connector	16″ Ribbon Cable
Dual-Transfer +SPDT	HP 33323K Opt. K31	HP 33323K Opt. K41

Switch Combinations with Attenuator Pads

It goes without saying that attenuator functions may be left in place to provide selector switching in combination with signal level control. Figure 12 shows a 70 dB attenuator consisting of 3-pads and adds to that an SPDT function on one end.

Several variations on that are already being used. One product consists of 1 transfer switch, 1 attenuator pad of 20 dB, and 1 SPDT switch function on the end. Another function has an SPDT switch selector on each end and three attenuator pads in the middle.

Attenuator Type	Viking Connector	16″ Ribbon Cable
70 dB +SPDT	HP 33323K Opt. K32	HP 33323K Opt. K42
110 dB +SPDT	HP 33323K Opt. K33	HP 33323K Opt. K43
20 dB +1 Transfer Switch +SPDT	HP 33323K Opt. K34	HP 33323K Opt. K44
70 dB +2 SPDT (1 each end)	HP 33323K Opt. K35	HP 33323K Opt. K45

Frequency Requirements Drive Performance

While these standard and custom products control signals all the way to 26.5 GHz, and are resonance-free, the isolation and line losses are naturally better in the dc to 1 or 4 GHz ranges. Considerable applications exist for those IF and low microwave requirements. Only the designer/reader knows that, and can use the best innovation to solve those system problems. And the capability to pack multiple functions into quite-compact programmable assemblies with high-reliability gives those designers a real solution.

New 5-Million-Cycle Reliability

An additional design consideration is that HP step attenuator structures are now warranted to full 5-million cycles on every pad. (A cycle is defined as an in/out cycle per pad.) For that life experience, typical repeatability at the end of the 5-million run is still <0.01 dB up to 18 GHz. And in exhaustive environmental tests at HP, many units are still performing well at 20-million cycles.

This exceptional performance resulted from a detailed engineering program which focused on understanding all the basic materials science effects going on and the variety of failure mechanisms. These ranged from flipper fatigue to the frictional-polymers which were building a contact debris on the pure gold wiping contacts, due to plasticizers in the materials. Interestingly, the literature on frictional polymers goes back 50 years (with ATT), but was not connected with microwave contacts under signal conditions until the last several years.

HP-IB Programmability

All of the switches, step attenuators, and combinations which are described in the above text are fully programmable with the HP-IB interface bus by use of the HP 11713A Attenuator/Switch Driver. It can handle up to 10 of the HP 33311/12/13 variety switches or 2 of the step attenuator products of the HP 33320/1/2/3 variety. The Driver is useful for designers because it supplies the solenoid drive power with appropriate diode circuit protection so that unique drivers need not be specially designed.

In addition to the above-described switch/attenuator combinations, the reader may conceive of other variations, and is encouraged to inquire of the HP Sales Representative about other such custom modifications.

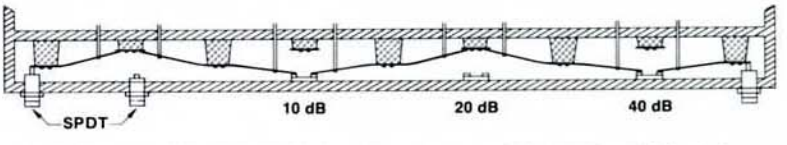


Figure 12. Combination 70 dB Step Attenuator with SPDT Coaxial Switch on left.

For more information, call your local HP sales office listed in the telephone directory white pages. Ask for the Electronic Components Department, or write to Hewlett-Packard:

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