Broadbanding the Shunt PIN Diode SPDT Switch

Application Note 957-1

In the design of a stripline or microstrip SPDT PIN diode switch, bandwidth and physical construction are often important considerations. Three basic design approaches for single pole, double throw diode switches are shown in Figures 1 through 3.

The series diode switch of Figure 1 is capable of very large (multi-octave) bandwidth, limited only by the bias inductors L and capacitors C, and the length of any transmission line between the diodes and the common junction. Etched flat spirals or aircore solenoids produce good broadband lumped-element inductors, and MOS capacitors feature self-resonant frequencies above 18 GHz. This structure is easiest to fabricate with beamlead diodes on alumina substrate MIC. In plastic dielectric symmetrical stripline, difficulty is encountered in relieving the faces of both boards to accept packaged diodes, and in locating the diode junctions electrically close to the common arm of the switch. Finally, parasitic capacitance gives rise to poor isolation at microwave frequencies, with a 6 dB per octave rolloff as a function of frequency.

The shunt diode switch, shown in Figure 2, features high isola-

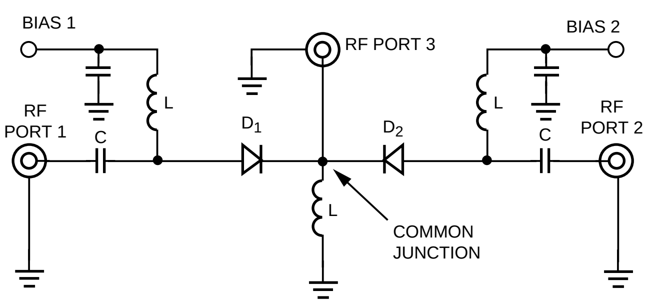

Figure 1. Series PIN SPDT Switch.

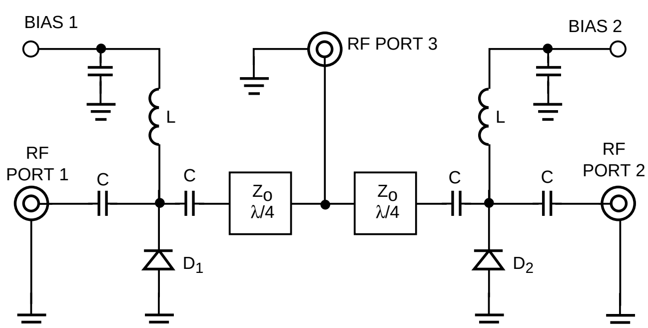

Figure 2. Shunt PIN SPDT Switch.

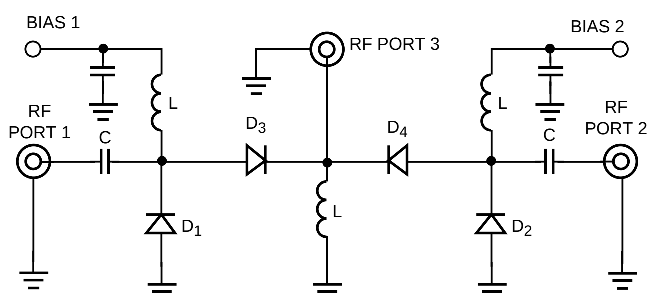

Figure 3. Series/Shunt PIN Switch.

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tion, relatively independent of frequency. It is an easy structure to design and fabricate if stripline package PIN diodes such as the HP 5082-3040 series are used. In these products, the diode junction capacitance has been matched out by integration into a low-pass filter structure. In an MIC switch, a chip, such as the HP 5082-0001, allows easy assembly. However, the user must then provide the matching structure. The main drawback of this type of switch is the bandwidth restriction arising from the use of quarter wavelength transmission lines between the common junction and each shunt diode. At the midband frequency f_O, where the transmission lines are $\lambda/4$ in length, the switch operates as follows: When Diode D_1 is forward biased and Diode D_2 is reverse biased, R.F. power will flow from Port 3 to Port 2, and R.F. Port 1 will be isolated. The $\lambda/4$ line will transform the short circuit at D_1 into an open circuit at the common junction, eliminating any reactive loading at that point. However, as the frequency is changed from f_O, the transmission lines will change in electrical length, creating a mismatch at the common junction. For example, when the ratio f/f_O or f_O/f is 1.2 (40% bandwidth), the VSWR of the structure will be 1.43:1.

To improve bandwidth without sacrificing isolation, a designer will often resort to the series/shunt circuit of Figure 3. When positive bias is applied to bias Port 1 and negative bias is applied to bias Port 2, Diodes D_3 and D_2 are forward biased into a low resistance state, while Diodes D_1 and D_4 are reverse biased into a high resistance state. R. F. power flows from RF Port 3 to RF Port 1. Diode D_4 acts as an open circuit to isolate the short at D_2

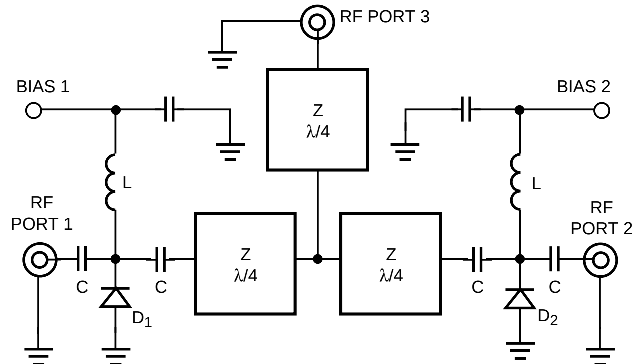

Figure 4. Broadband Shunt SPDT Switch.

from the common junction. This switch, however, is complicated, and consumes twice the bias power of the shunt switch shown in Figure 2. Here, as in Figure 1, it is difficult to mount the D_3 and D_4 diode junctions electrically close to the common arm.

The bandwidth of the shunt diode switch can be improved by the simple impedance matching technique shown in Figure 4. A third transmission line, a quarter wavelength long at f_O, is placed between the common junction and RF Port 3. In addition, the impedance of all three lines is set to some value, Z, below 50 ohms. The specific value of impedance that is chosen will determine the SWR and bandwidth of the switch. Figure 5 gives the SWR vs. bandwidth for five values of Z. For example, setting the impedance of the three transmission lines to 35 ohms results in a 1.43:1 SWR bandwidth of 100% (3:1), a significant improvement over the bandwidth of the switch shown in Figure 2. The data shown on Figure 5 was computed assuming a resistance of 0.5 ohms for D_1 and 1000 ohms for D_2.

By selecting the impedance for the transmission line of Port 3 to be slightly different from the

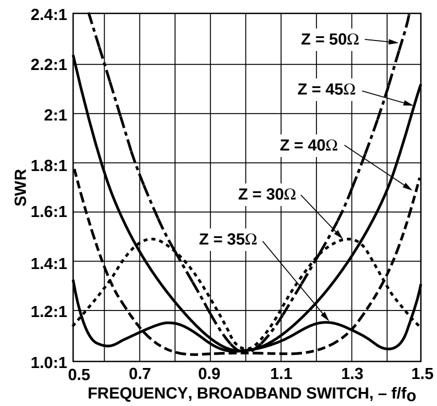

Figure 5. SWR vs Frequency Ratio, Broadband Switch.

other two, small additional improvements in SWR can be made. This variation of the broadbanding technique is beyond the scope of this note, but it can be easily and quickly evaluated by means of one of the many microwave circuit analysis programs available on timeshared computers.

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Obsoletes 5952-0710
Printed in U.S.A. 5964-3902E (1/96)