Compact HSMP-389V Transmit/Receive Switch Design

Application Note 1163

Introduction

The series-shunt configuration transmit/receive switch using PIN diodes as shown in Figure 1 has been in use for many years. It offers several advantages compared to switches configured only with series diodes. First, the biasing is simple with only one control line. Second, the switch only requires bias while in transmit mode. And third, both diodes are biased when the PA is delivering power. This third advantage grows in importance at higher frequencies as “off ” PIN diodes are usually the elements responsible for generating harmonics either due to modulation of the diode’s capacitance or self-biasing from rectification of the transmitted signal. This behavior tends to get worse as the frequency increases. On the other hand, harmonic distortion generated by biased “on” PIN diodes reduces as frequency increases.

Description

In transmit mode bias current is applied to the switch and this current biases both PIN diodes in d.c. series bringing them both to a low resistance state. This connects the transmitter power amplifier to the antenna and puts a short-circuit across the receiver input to protect it from high input levels. This short-circuit is rotated to an open-circuit at the antenna port by the quarter wave (90°) transmission line, thus ensuring that the transmit path is not loaded. In receive mode, no bias current is applied therefore making both diodes high resistance. This disconnects the transmitter from the antenna port and removes the

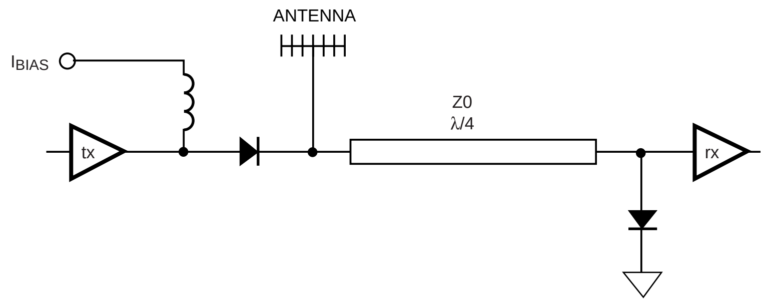

Figure 1. Series-shunt Transmit/Receive Switch using PIN Diodes

short-circuit across the receiver port which connects the antenna to the receiver. To help avoid harmonic generation problems it is a good idea to ensure that the bias circuit is high impedance when in the no bias state.

This arrangement has been used previously in time division duplex (TDD) digital mobile phones and PMR (SMR) transceivers using perhaps two SOT23 package PIN diodes and a microstrip or other quarterwave transmission line. This works effectively but uses up a significant amount of board area. With the continual pressure to reduce the size and weight of mobile terminals and with the introduction of dualband designs, a smaller solution is needed. This can be partly achieved by putting both the series and the shunt diode in one small SOT363 package as in the case of the HSMP-389V. Using a lumped element equivalent circuit as shown in Figure 2 can also considerably reduce the space required for the quarterwave line as this can be designed with small size surface-mount components.

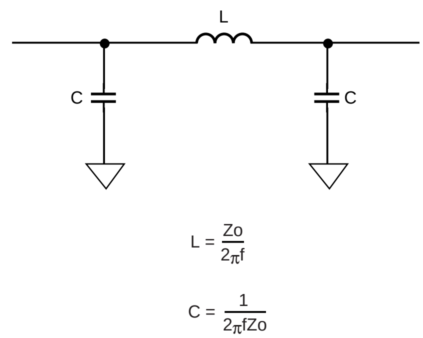

Figure 2. Lumped Element 90° Phase Shifter

For good high frequency operation it is important that the parasitic series inductance of the shunt diode be kept as low as possible; this will ensure good isolation in the receive path. The HSMP-389V has two special internal construction features that give this; the shunt diode has two parallel ground leadframe connections and a “through path” connection to the top of the diode die. The use of a low capacitance PIN diode die ensures low loss in this “through path” and also good isolation in the transmit path series switch. The equivalent circuit of the HSMP-389V is shown in Figure 3. This can be used in linear simulations by adjusting the two resistors between 5 kΩ (unbiased) and 2 to 1 Ω (5 to 10 mA bias). Refer to the “RF Resistance vs. Forward Bias Current” graph in the data sheet for other bias conditions.

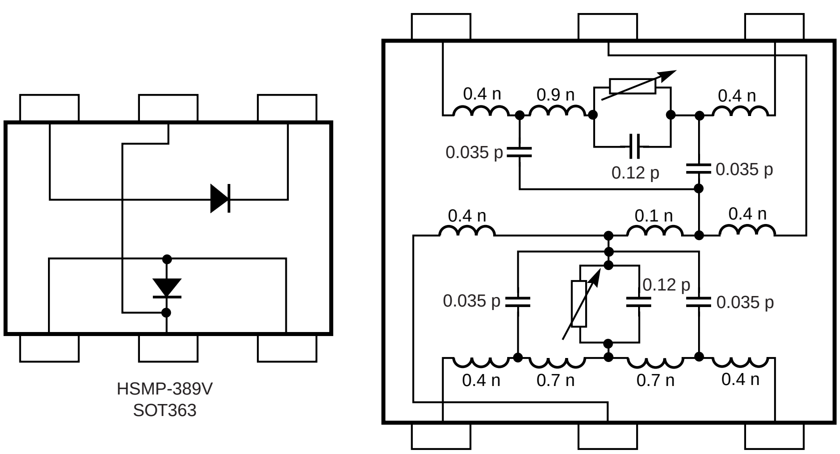

Figure 3. Equivalent Circuit of the HSMP-389V

Demoboard Design

Figure 4 shows the circuit diagram of a demoboard designed to allow transmit/receive switches to be built over a wide frequency range. Component values and results for three examples are given in this application note, at 400 MHz, 900 MHz and 1.9 GHz. The demoboard includes the component positions for a lumped element quarterwave transmission line as discussed. The track pattern and assembly drawing for the board are shown in Figures 5 and 6 respectively.

The demoboard component values for a quarterwave line can be calculated from the following equations: $C5 = C6 = 1/(2\pi f Zo)$ and $L3 = Zo/(2\pi f)$. At higher frequencies, however, the phase length needs to be made less than 90° to allow for the path length on the board and to compensate for some internal package series inductance of the HSMP-389V. For example, the phase angle should be 75 degrees at 900 MHz. The initial circuit values for these designs were determined from a simple linear simulation on “Touchstone for Windows” and the netlist for the 900 MHz example is shown in Appendix 1. Some adjustments were made to the simulated component values to accommodate the use of preferred component values and small amounts of stray capacitance on the board. In general, the nearest lower preferred value is chosen for the inductor L3 and the capacitors C5 and C6 are perhaps 0.4 pF lower in value.

Component values for the three example frequencies are shown in Table 1. The capacitors used were from ROHM MCH18 range and the inductors were either TOKO types LL1608 or LL2012 depending on their value. The printed board is designed to accept edge-mounting SMA connectors such as Johnson Components, Inc., Model 142-0701-881. These connectors are designed to slip over the edge of 0.8 mm (0.031-inch) thick circuit boards and obviate the need to mount PCBs on a metal base plate for testing.

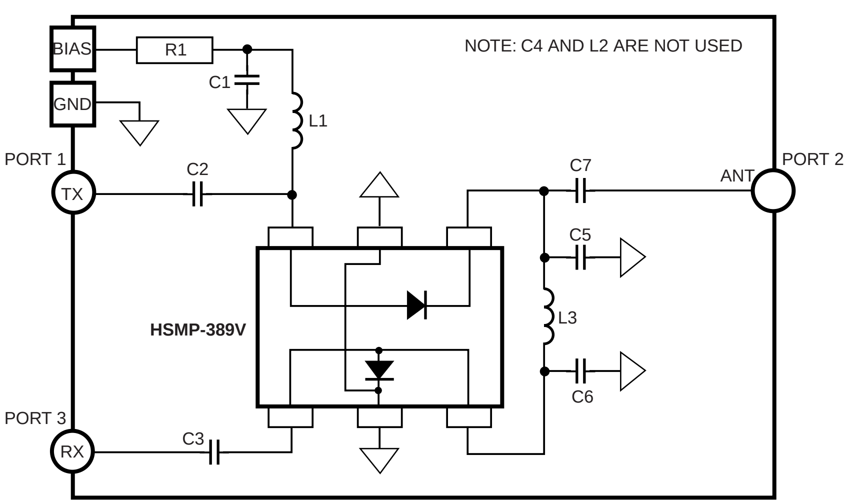

Figure 4. Demoboard Circuit Diagram

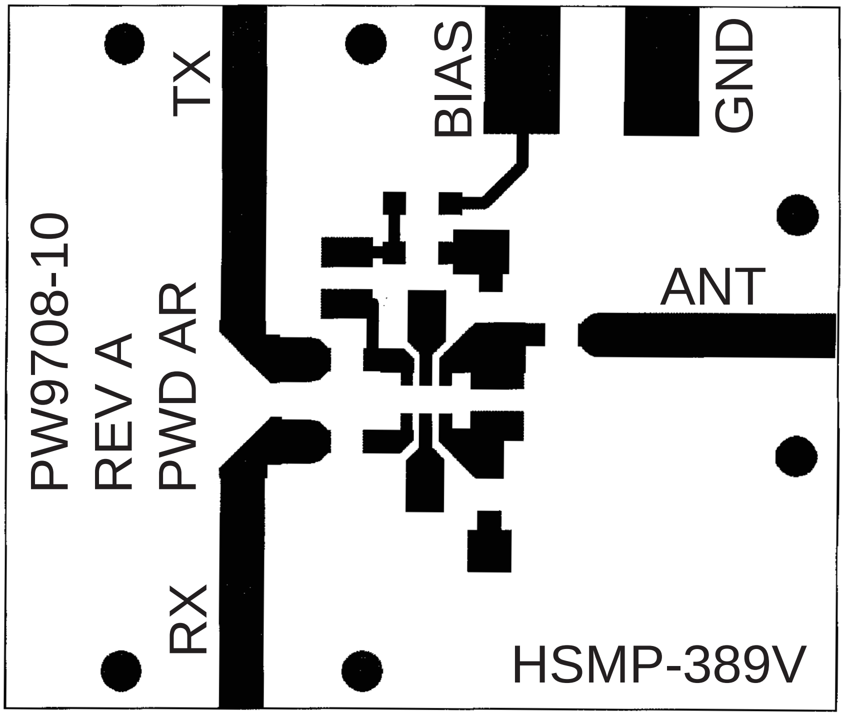

Figure 5. Track Pattern for Demoboard

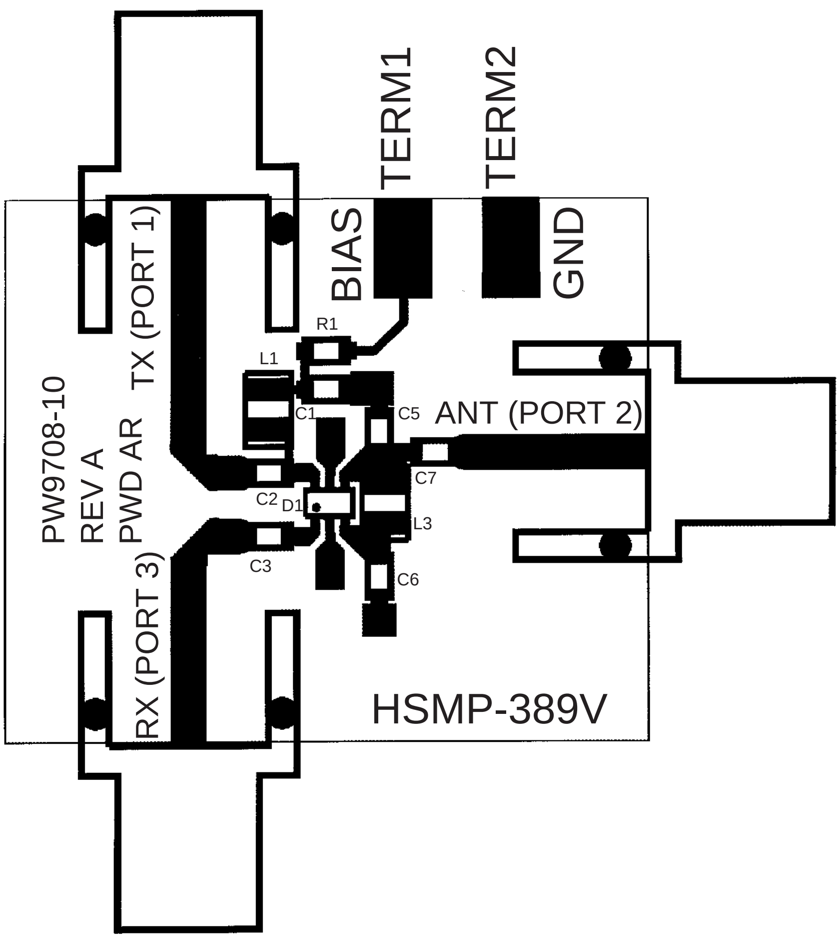

Figure 6. Assembly Drawing for Demoboard

Table 1. Component Values for Three Frequencies

	400 MHz	900 MHz	1.9 GHz
R1/Ω	390	390	390
C1/pF	220	220	220
C2/pF	220	15	10
C3/pF	100	33	3.3
C5/pF	6.8	2.2	1.0
C6/pF	6.8	2.2	1.0
C7/pF	220	220	47
L1/nH	120	220	100
L3/nH	18	8.2	3.9

Results

Results from the simulation of the circuit for the 900 MHz example are shown in Figures 7 and 8. With this tx/rx switch configuration, the transmit path response has low loss over a fairly wide band while the receive path exhibits a useful low-pass response due to the lumped element quarterwave line.

The value of R1 on the demoboard sets the diode bias current for a given switch control voltage; the value of 390 Ω gives around 5 mA at 3 V. The transmit path loss can be improved slightly by increasing the bias current to perhaps 10 mA either by using a higher supply voltage or reducing the value of R1. L1 and C1 decouple the bias input from the r.f. path. At lower frequencies the value of L1 can also be chosen to help improve the match of the transmit port.

On the demoboard, C2 provides d.c. blocking and the value is chosen to tune for best match of the transmit port while C3 is used in the same way for the receive port. C7 provides d.c. blocking for the antenna port. In a real implementation of this circuit, these elements may be absorbed into matching for other preceding or following circuitry such as the low noise amplifier.

Measured results from the demoboard for the loss and isolation at the three example frequencies are given in Table 2. In addition, the input/output match of the active ports was better than -20 dB in all three cases.

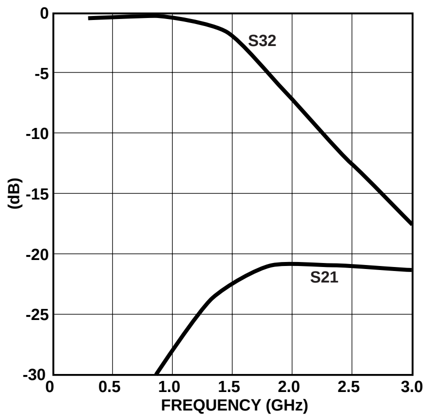

Figure 7. 900 MHz Switch, Rx Mode Simulation

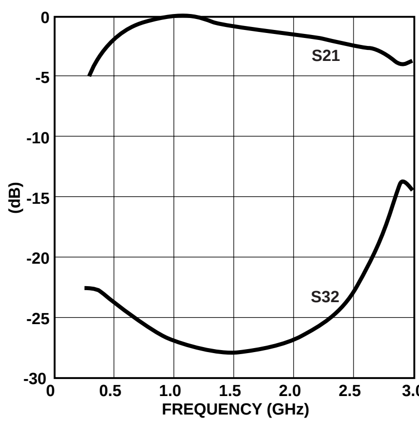

Figure 8. 900 MHz Switch, Tx Mode Simulation

Summary

The results from these demoboard examples show the potential use of the HSMP-389V in transmit/receive switch designs for transceivers in various systems. Good loss and isolation performance is achieved in a switch which takes comparatively little space. Example applications include PMR(SMR) such as TETRA, mobile phones such as GSM or PCS, and DECT cordless phones. The small size of the switch also makes it suitable for dualband terminal designs as shown in the suggested arrangement in Figure 9.

Table 2. Measured Results for Loss and Isolation

	400 MHz	900 MHz	1.9 GHz
Tx: Tx-Ant/dB	-0.4	-0.45	-0.6
Tx: Tx-Rx/dB	-32	-32.5	-30
Rx: Ant-Rx	-0.1	-0.4	-0.6
Rx: Ant-Tx	-35	-25.5	-23

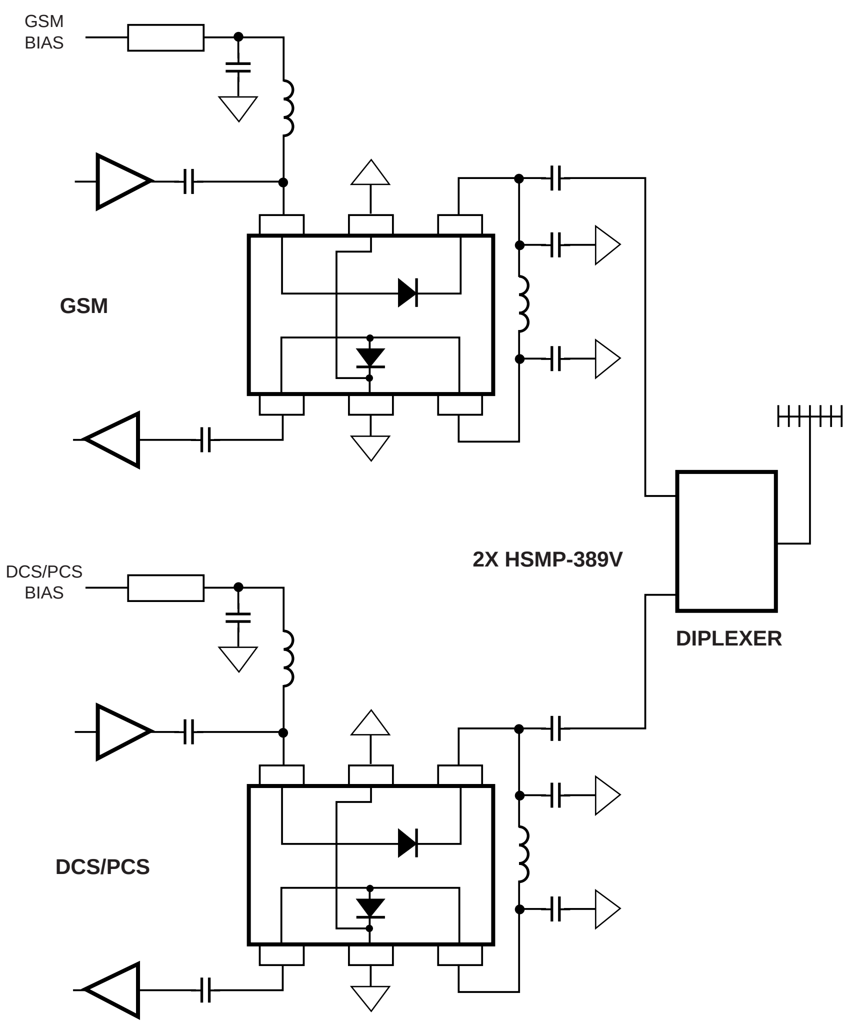

Figure 9. Suggested Arrangement for Dualband Terminal

Appendix 1. Touchstone for Windows File

```
! FILENAME: HSMP-389V Demoboard @900MHz
!
DIM
        FREQ    GHZ
        RES     OH
        IND     NH
        CAP     PF
        LNG     MIL
        TIME    PS
        COND    /OH
        ANG     DEG
VAR
        ra=5000         !diode unbiased  (toggle)
!       ra=2            !diode 5mA bias (toggle)
        cs=0.4          !stray capacitance
        lb=220          !L1
        lq=8.2          !L3
        cb=220          !C1
        ct=15           !C2
        cr=33           !C3
        cq=2.2          !C5 and C6
        ca=220          !C7
CKT
        ind 1 2 l=0.4
        ind 2 3 l=0.9
        res 3 4 r^ra
        cap 3 4 c=0.12
        ind 4 5 l=0.4
        ind 6 7 l=0.4
        ind 7 8 l=0.7
        ind 8 9 l=0.7
        ind 9 10 l=0.4
        res 8 11 r^ra
        cap 8 11 c=0.12
        ind 11 0 l=0.4
        ind 11 12 l=0.1
        ind 12 0 l=0.4
        cap 7 11 c=0.035
        cap 9 11 c=0.035
        cap 2 12 c=0.035
        cap 4 12 c=0.035
        def4p 1 5 6 10 hpv        !HSMP-389V model
        cap 1 2 c^ct
        ind 2 9 l^lb
        cap 9 0 c^cb
        cap 3 0 c^cq
        ind 3 4 l^lq
        cap 4 0 c^cq
        hpv 2 3 5 4
        cap 3 7 c^ca
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```
        cap 5 6 c^cr
        cap 2 0 c^cs
        cap 3 0 c^cs
        cap 4 0 c^cs
        cap 5 0 c^cs
        def3p 1 7 6 hpsw          !switch circuit
FREQ
        sweep 0.3 3 0.05
OUT
        hpsw db[s21] gr1          !tx-ant loss
        hpsw db[s32] gr1          !ant-rx loss
GRID
        freq 0 3 0.5
        gr1 -30 0 5
        gr2 -30 0 5
```

www.hp.com/go/rf
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Data Subject to Change

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