GaAs MONOLITHIC IMPLEMENTATION OF ACTIVE CIRCULATORS

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ABSTRACT

A GaAs monolithic three-transistor signal circulator for 0.2 to 2 GHz applications has been developed and tested. The three-terminal device demonstrates 6 dB insertion loss and 18 dB directivity over this frequency range.

INTRODUCTION

A circulator is a three-terminal device which passes signals incident on one port to the next port in either a clockwise or counter-clockwise sense, and does not allow signals to pass in the opposite sense. Although the most familiar types of microwave frequency circulators are constructed using passive magnetic techniques, it is possible to construct active circulators based on transistors, as described by S. Tanaka et al. (1).

DESIGN

In the previously mentioned work, an active circulator was constructed which was operational to a highest frequency of 3 MHz, but the authors point out that the isolation of the device is limited by the frequency characteristics of the transistors. The focus of this work, then, was to apply the advantages of GaAs monolithic circuit technology to extend the useful frequency range of this type of circuit. The schematic diagram of the circulator circuit is shown in Figure 1. The sources of the three GaAs FET's are tied together, and a common source resistor allows interaction between the devices. Another feedback mechanism is introduced by the shunt feedback resistor between the drain and gate of each transistor. By properly adjusting the values of the resistors and the sizes of the transistors in the circuit, port matches and a null in the reverse transmission characteristic may be simultaneously obtained. This process, along with numerically derived design curves, is detailed in (1).

These techniques have been utilized to design the GaAs circuit of Figure 2. The circuit consists of three 150 micrometer gate width FET's of gate length 0.5 micrometer, three capacitors, and seven GaAs resistors. The resulting chip size is 1.1 x 1.0 mm on a

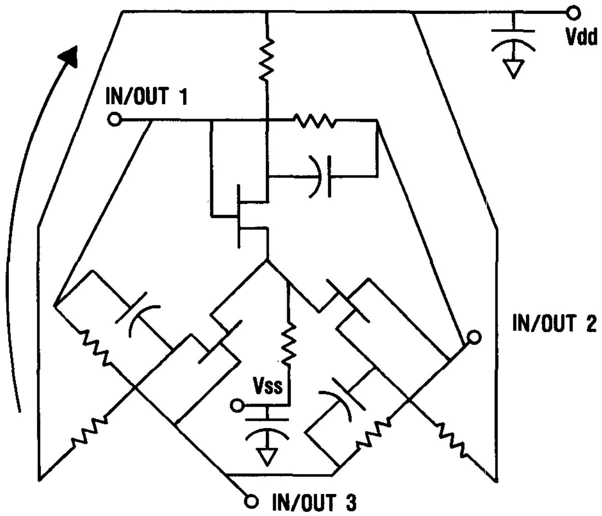

Figure 1. Active Circulator Schematic Diagram

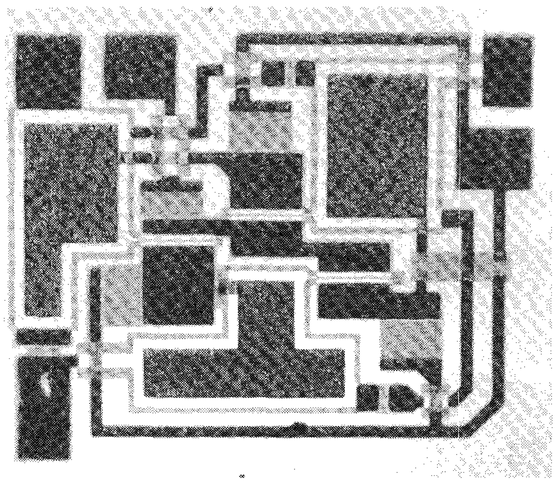

Figure 2. The GaAs Monolithic Active Circulator Chip

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substrate of thickness 0.15 mm. The ability afforded by monolithic construction techniques to locate the active devices in close proximity to each other and avoid interconnecting circuitry stray capacitance is critical to the high frequency operation of the device.

MEASURED PERFORMANCE

Figure 3 shows the device mounted in a small housing with SMA connectors. At bias conditions of

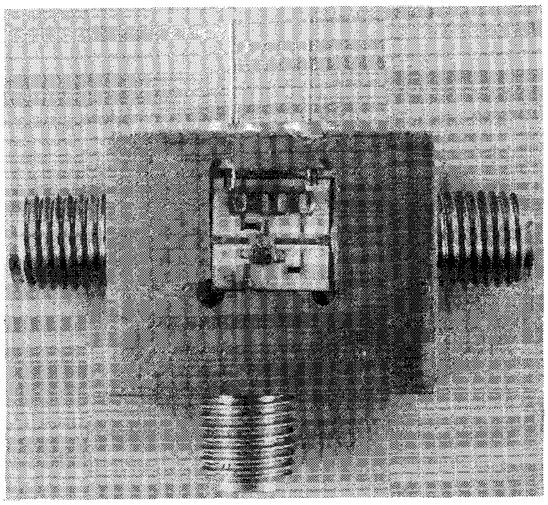

Figure 3. Active Circulator Module

+8 V at Vdd and -3.75 V at Vss, the circuit draws 25 mA. A plot of the return loss at one input port is seen in Figure 4. Over the 0.2 to 2 GHz frequency range, the return loss is greater than 15 dB. Figure 5 shows the insertion loss of a forward path through the circulator. This loss is a very constant 6 dB. The insertion loss of the device through a reverse path is seen in Figure 6.

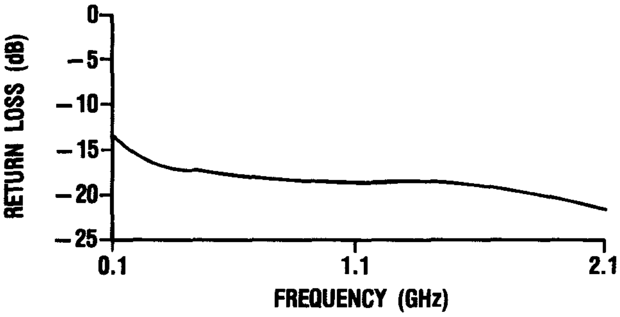

Figure 4. Circulator Port Return Loss

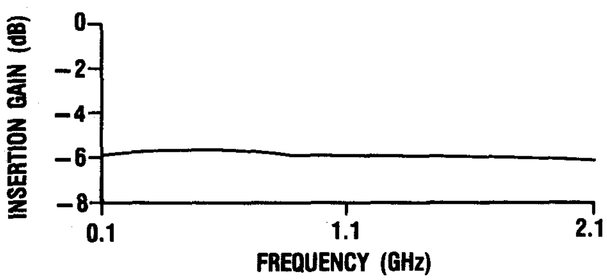

Figure 5. Circulator Forward Path Insertion Gain

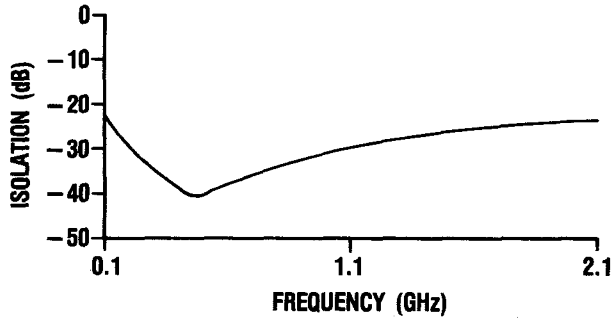

Figure 6. Circulator Reverse Path Isolation

This isolation has a maximum of over 40 dB at 400 MHz and is greater than 24 dB across the entire band. This corresponds to a minimum directivity of 18 dB. The factors which limit the isolation of the device are the reactance of the on-chip dc blocking capacitors at low frequencies and the FET parasitic capacitances at high frequencies.

Although both the insertion loss and the power handling capability of this device preclude its use at the antenna port of a transceiver, where the use of passive circulators is common, other applications for such a circuit exist. One such application might be an extremely small reflection test instrument for testing antenna VSWR or transmission line integrity in the field. As in the block diagram of Figure 7, if a voltage controlled oscillator and an RF detector were used in conjunction with the active circulator, the detector voltage would indicate the return loss of the device under test.

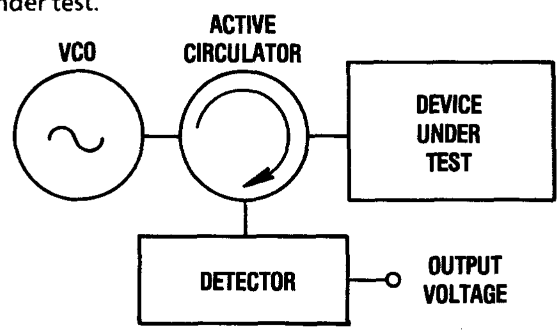

Figure 7. Block Diagram of a Reflection Test Instrument Utilizing an Active Circulator

CONCLUSION

In conclusion, GaAs monolithic techniques have been utilized to extend the useful frequency range of the active circulator topology proposed by Tanaka et al. The circulator realized is operational across the 0.2 to 2 GHz band with an 18 dB difference between forward and reverse path insertion losses.

ACKNOWLEDGMENT

The author thanks J. Vaillancourt for his help with the assembly and testing of the circulator modules.

REFERENCE

(1) S. Tanaka, N. Shimomura, and K. Ohtake, "Active Circulators -- The Realization of Circulators using Transistors," PROC. IEEE, vol. 53, no. 3, pp. 260-267, Mar. 1965.