1 - 6 GHz GaAs MMIC LINEAR ATTENUATOR WITH INTEGRAL DRIVERS

G. Lizama, T. Andrade, R. Benton

Pacific Monolithics, Inc.
245 Santa Ana Court
Sunnyvale, CA 94086

ABSTRACT

This paper describes the performance of a voltage-controlled attenuator with a 12 dB linear attenuation vs. control voltage range. This linear attenuator greatly facilitates the realization of both closed and open loop gain compensation networks. Over the -55^{O}C to 85^{O}C range the attenuator recorded a 7.2 $\pm$ 1 dB/V linear transfer function while using only 25 mW from a single 4 V power supply.

INTRODUCTION

As with MIC systems, MMIC systems must also meet temperature stabilization requirements in order to realize their advantages. PIN diodes together with quadrature hybrids are commonly used in MIC attenuator designs [1], but these elements are not available to the MMIC designer at reasonable cost. For an MMIC variable attenuator, using the gate voltage control of the MESFET drain-source resistance is one alternative for variable attenuator implementation. For this attenuator control, a linear voltage to RF attenuation transfer function is desirable, because the control voltage vs. temperature is usually a linear function of temperature, eliminating the need for complicated off-chip circuitry. The linear change in the forward voltage drop of a diode with temperature, when amplified, could then be used to control the attenuator and provide a linear attenuation change vs. temperature.

ATTENUATOR DESIGN

The attenuator design required a topology which could be optimized to obtain adequate attenuation linearity vs. control voltage, attenuation range, and bandwidth. For the attenuator design we view the MESFET as a voltage controlled resistor with voltage dependent gate-source and gate-drain capacitances, and a voltage independent drain-source capacitance. The T attenuator topology was chosen over the pi because of its increased bandwidth [2]. The basic attenuator topology is shown in Figure 1.

To achieve minimum insertion loss, the series FETs must have the smallest possible on-resistance. This may be accomplished through the use of moderate area MESFET periphery, and forward biasing the gate. It should be noted that while the on-resistance decreases

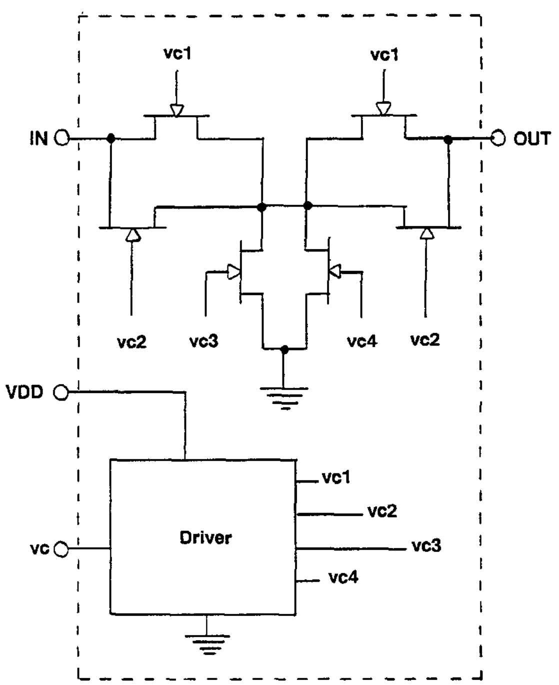

FIGURE 1. LINEAR ATTENUATOR SCHEMATIC DIAGRAM

with increased MESFET gate periphery, the drain-source capacitance increases, and at higher frequencies this dominates the device off-state impedance. The nonlinear property of Rds vs. Vgs is overcome by placing a smaller periphery MESFET in parallel with the series control MESFET, the periphery ratio being optimized to provide the best attenuation linearity. With four MESFET widths and four unique control voltages, a design target of 10 dB linear range can be achieved.

Both attenuator range and frequency bandwidth are degraded by the capacitances of the shunt and series MESFETS. At high frequencies and in the maximum attenuation state, the T attenuator resembles a high-pass filter, with the series MESFET Cds and the shunt bondwire inductances dominating. This is illustrated in Figure 2. This problem causes the insertion loss to decrease with increasing frequency, which degrades the useful attenuator bandwidth. Additional bandwidth is achievable by replacing the bond wires with via-hole grounds but only at the expense of higher processing cost.

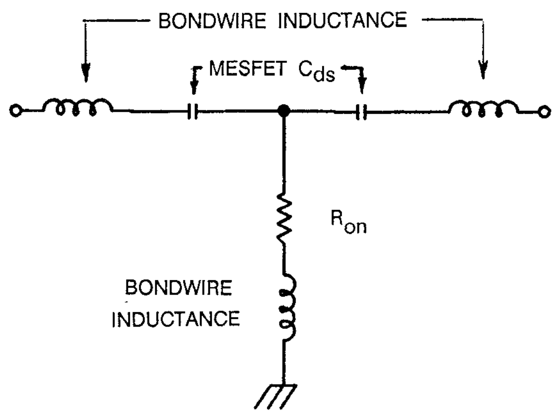

FIGURE 2. ATTENUATOR ILLUSTRATED AS A HIGH-PASS FILTER.

The linear attenuator was built with one micron gate-length MESFETS with a nominal pinchoff voltage of -1.5 V. A temperature sensing diode was placed on-chip for external control of the attenuator in temperature compensation applications. The series and shunt MESFETs float at VDD and allow the circuit to work from a single positive supply. A bypass capacitor is therefore necessary on the shunt MESFETs and this capacitance limits the low frequency response. High value resistors connect the MESFET nodes to the appropriate control and bias voltages.

THE INTEGRATED DRIVER

The integrated driver provides gate voltages to the series and shunt MESFETS. A simple inverter is used to provide the necessary complementary voltage curve for the shunt MESFETS. The MESFETs used in the driver have the same pinchoff voltage as was used in the attenuator elements. A maximum power consumption of 25 mW is required by the 100 um x 200 um driver, which provides the attenuator with a response time of less than 5 nanoseconds. Electrostatic protection circuitry was also included on the driver input lines.

RESULTS

The attenuator chip was die attached with epoxy and bonded onto a thin film environment with one mil gold wire. The 900 um x 900 um chip with 100 um square bonding pads is shown in Figure 3. The measured RF performance is shown in Figures 4 and 5. Over the 1-6 GHz range, the minimum insertion loss was between 2 and 2.5 dB. The return loss was better than 10 dB over the entire frequency range. Linear attenuation range achieved was 12 dB, while the maximum attenuation recorded was 25 dB. The attenuator handled up to 20 dBm of RF input power with no change in attenuation.

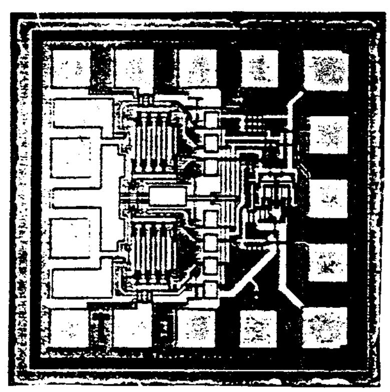

FIGURE 3. LINEAR ATTENUATOR PHOTOMICROGRAPH.

The insertion loss vs. control voltage over temperature is shown in Figure 6. This illustrates the linearity of the attenuator. At low insertion loss states there is a noticable insertion loss variation with temperature. We have used this variation to temperature-compensate moderate gain amplifiers without any additional circuitry. This variation is probably due to the driver sensitivity to temperature, which results in some variation of voltage to the gates on the series and shunt MESFETs.

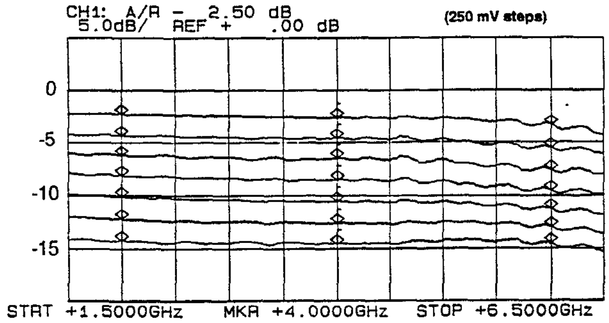

FIGURE 4. ATTENUATION vs. FREQUENCY.

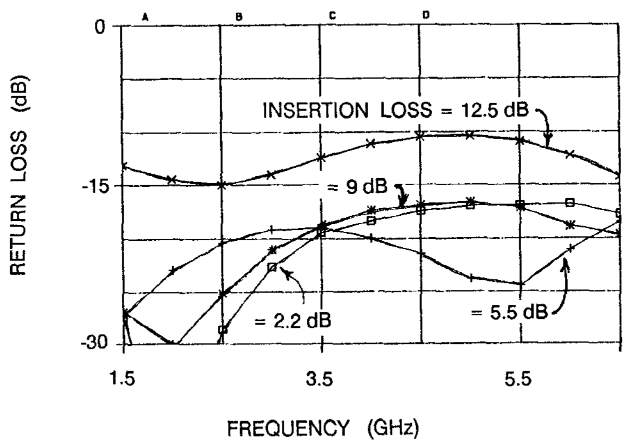

FIGURE 5. INPUT/OUTPUT RETURN LOSS AT VARIOUS CONTROL VOLTAGE LEVELS.

CONCLUSION

A GaAs linear, voltage-controlled attenuator with on-chip drivers has been designed and tested. It has the advantages of small size, low power consumption, and the need for only a single control voltage and a single supply, increasing its usability.

ACKNOWLEDGEMENTS

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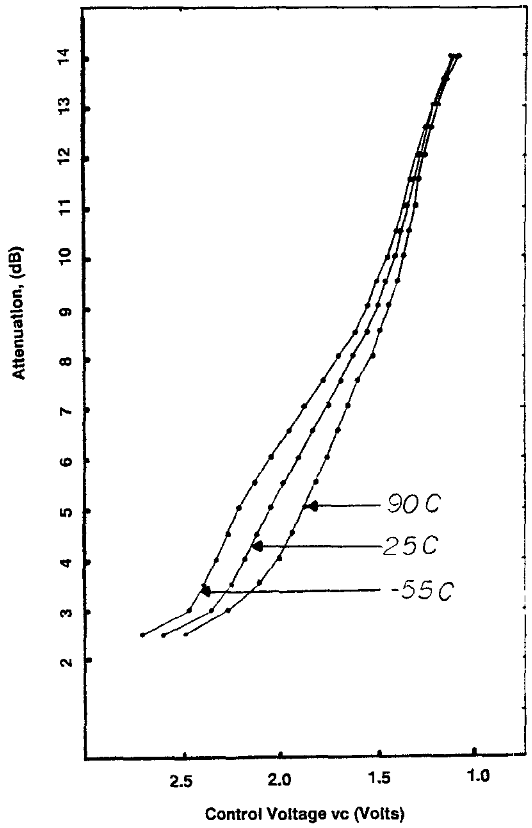

FIGURE 6. LINEAR ATTENUATOR TRANSFER CHARACTERISTICS.

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