# GaAs "TRAVELING-WAVE" TRANSISTOR

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Abstract

Present packaged GaAs "traveling-wave" transistors produce instantaneous 5-20 GHz CW net gain with 17 dB X-band noise figure. The devices employ self-aligned input electrodes. A versatile new broad-band microwave package has been developed.

The GaAs traveling-wave transistor is a small-signal microwave amplifier that combines a GaAs Schottky-barrier field-effect transistor with a thin-layer transferred-electron traveling-wave amplifier. The GaAs FET input section produces a charge-density fluctuation which passes into a long traveling-wave drift region instead of into the usual load resistor. The signal is carried through the traveling-wave region from cathode to anode in the form of a traveling space-charge wave, and it undergoes a broad-band exponential growth as it moves. At the anode end of the device, charge associated with the wave is discharged into an output transmission line attached between a small output electrode and the anode contact. By providing a large spacial separation between input and output, the traveling-wave region makes it possible to obtain a very high gain-bandwidth product.

The maximum broad-band stable gain is established by two forms of output-to-input feedback. There is an internal feedback mechanism (1) which is essentially the same as the feedback mechanism which causes supercritical Gunn diodes to oscillate. There is also an external or circuit feedback mechanism (2) associated with coupling between the output and input transmission lines. The internal (Gunn diode) feedback mechanism limits the traveling-wave gain to less than about 30 dB. It is fundamental to the traveling-wave part of the device and is not easily modified. The external (circuit) mechanism limits the overall gain, which can be greater than the traveling-wave gain if the input and output contribute to the gain. The external feedback can be made almost arbitrarily small by proper device and circuit design.

Present packaged devices produce stable instantaneous CW net gain from about 5 GHz to about 20 GHz, as shown in Fig. 1. The best noise figure achieved to date is 17 dB at 9.3 GHz with 10 dB net gain. The forward-to-reverse gain ratio (isolation) is 50 to 36 dB between 8 and 16 GHz, under normal operating conditions. Compared to the best previously reported 12 GHz results (2), the isolation is about 25 dB greater, the gain-bandwidth product is about 8 dB higher, and the noise figure is about 7 dB lower. Independent voltage-controlled amplitude and phase modulation are observed, as in previous devices.

The performance improvements have been due to improvements in both device fabrication and circuit design. The material employed for the devices is vapor-grown epitaxial gallium arsenide, with 0.4 μm of $n^+$ on 1.0 μm of $5 \times 10^{15}$ n on chromium-doped semi-insulating substrates. We will show how the in-situ-grown $n^+$ capping layer makes it possible to obtain very low resistance ohmic contacts: After the ohmic contact metallization is deposited on the top surface, the exposed $n^+$ is etched away; then when the final input and output Schottky-barrier electrodes are evaporated, the metallic edge of the cathode ohmic contact serves as a shadow mask which enables the input gate electrode to be aligned very close to the cathode. This self-aligned procedure further reduces the gate-to-source resistance of the input FET section.

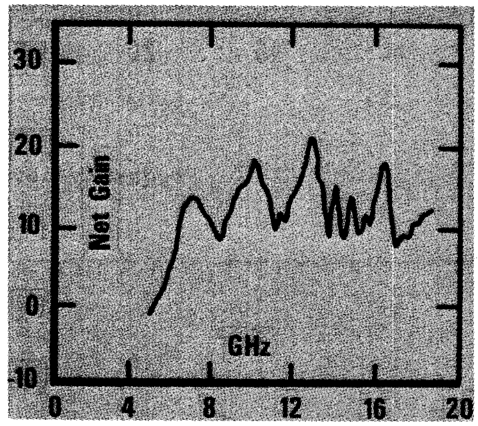


Fig. 1 Instantaneous Net Gain vs. Frequency

As the input section is made better, it becomes more advantageous to improve the packaging so that external or circuit feedback effects are reduced and isolation is improved. For most of the current results, we have employed a 50-ohm OSSM package, with bias voltages applied to the input and output electrodes through bias tees in the external RF circuit as well as to the package itself. For future devices we have developed a new package which itself accommodates all bias connections. This package will be seen to have the form of a 1/2" copper cube with either OSM or OSSM connectors mounted on opposite faces. A 0.360" diameter cylindrical hole in the bottom of the cube accepts a standard transistor or integrated-circuit header, on which is mounted not only the device chip but also

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bypass capacitors, input and output bias tees and blocks, and input and output quarter-wave microstrip matching sections. All bias connections are made to the pins of the header, it is very easy to mount and demount devices, and broad-band microwave tuning is facilitated. Both packages have good microwave properties in the frequency range 4-18 GHz.

With further improvements in the device, we expect to increase the average gain in the 8-16 GHz range to about 35 dB and to increase the total net-gain bandwidth to over a decade. In addition, we expect to reduce the X-band noise figure to about 6 dB. The device has ultimate application as a general-purpose, high-gain-bandwidth, small-signal amplifier and signal processor.


1. R. H. Dean, "Reflection Amplification in Thin Layers of n-GaAs," IEEE Trans. on Electron Devices, ED-19, p. 1148 (1972).

2. R. H. Dean and R. J. Matarese, "The GaAs Traveling-Wave Amplifier as a New Kind of Microwave Transistor," Proc. IEEE, December, 1972.

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