A 12.5GHz DIVIDE-BY-EIGHT PRESCALER IN GaInP/GaAs HBT TECHNOLOGY

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ABSTRACT

A fully integrated pre-amplifier and a static divide-by-eight prescaler clocking at 12.5GHz realized in a GaInP/GaAs HBT technology is presented. The HBT process incorporates Schottky diodes, nichrome resistors, MIM capacitors and air-bridge inductors. HBTs with emitter size of 3μ ×10μ have current gains of 145 and f_T and f_{max} of 60GHz and 45GHz respectively. Unloaded ECL gate delays of 28ps are obtained from ring oscillator measurements.

INTRODUCTION

The ability to build HBT integrated circuits routinely has opened up a variety of high-speed applications. In particular, the AlGaAs/GaAs HBT IC technology enjoys overall maturity and has become the work horse for several analog, digital and microwave applications. However, achieving high current gains in AlGaAs/GaAs system is rather difficult. The GaInP/GaAs system provides a small conduction-band offset (0.16eV) and a large valence-band offset (0.29eV) which is very desirable for HBTs [1]. Due to the small conduction-band offset, compositional grading of the emitter-base junction is not required. Compared to AlGaAs/GaAs, the GaInP/GaAs system is free from DX centers and it is the preferred material system due to highly selective chemical etchants for GaInP. In this paper, we demonstrate circuits realized in GaInP/GaAs HBT technology.

PROCESS DESCRIPTION

The HBT structure needs only five grown layers as shown in Table.1. The layers were grown by OMVPE at Epitronix Corporation. The devices were fabricated using a standard mesa etch process as shown in Fig.1. All the GaAs layers were etched using H_3PO_4/H_2O_2 and the GaInP emitter mesa was defined by H_3PO_4/HCl etchant [2]. After etching the collector, isolation and Schottky mesas, the devices were passivated with a layer of nitride. A 50 ohms/sq. NiCr layer is then deposited and n and p-ohmic regions are subsequently defined. Au/Ge/Ni contacts are used for the emitter and collector and Au/Mn contacts are used for the base.

Table 1. Epitaxial structure used for HBTs.

Layer	Composition	Dopant	Doping (cm^{-3})	Thickness (Å)
Cap	GaAs	Si	5×10^{18}	1000
Emitter	GaInP	Si	5×10^{17}	1000
Base	GaAs	C	4×10^{19}	500
Collector	GaAs	Si	3×10^{16}	5000
n+ Collector	GaAs	Si	5×10^{18}	5000
Substrate	GaAs		S.I.	508u

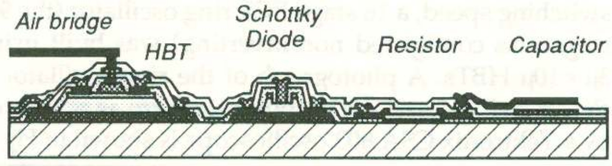

Fig.1. GaInP/GaAs HBT IC process.

After alloying, the contact resistivity of p-ohmics was 7×10^{-7} ohm-cm^2 with a base sheet resistance of 485 ohms/sq. Another layer of nitride is then deposited, contact vias are etched and first level metal (Ti/Au) is evaporated forming anodes for Schottky diodes and bottom electrodes for the capacitor. After depositing the capacitor nitride, a plated air-bridge layer is defined which forms air-bridge inductors and top electrodes of the capacitors.

DEVICE PERFORMANCE

The current gain of 3μ × 10μ HBTs at I_C=10mA is 145 and a β of 40 can be achieved even at a collector current of 1μA as seen from the Gummel plot in Fig.2.

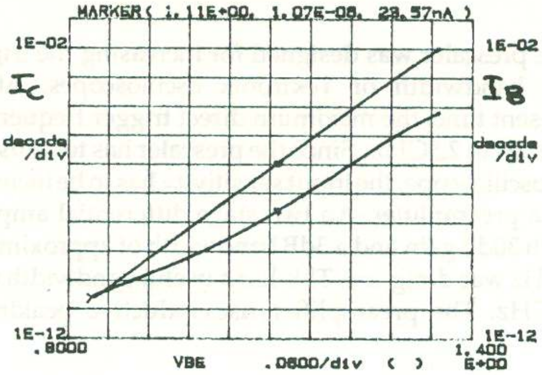

Fig.2. Gummel plot of a 3μ × 10μ HBT.

S-parameters of $3\mu \times 10\mu$ HBTs were measured from 40MHz to 40GHz. The device was biased at I_C=20mA and V_{CE}=2V and the results are shown in Fig.3.

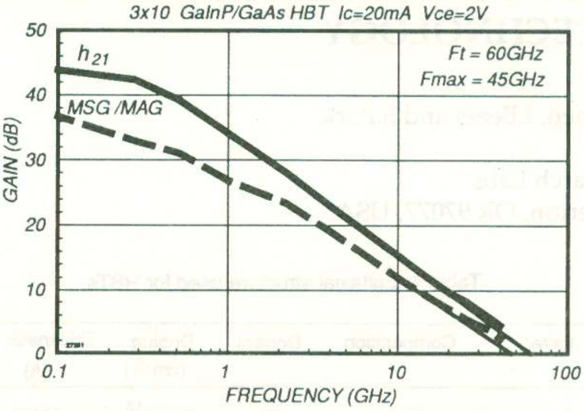

Fig.3. Microwave performance of $3\mu \times 10\mu$ HBT.

By extrapolating the current gain h_{21} we obtain an f_T of 60GHz. From the maximum available gain (MAG), we obtain an f_{max} of 45GHz. The devices have BV_{CBO}, BV_{CEO} and BV_{EBO} of 17, 10 and 8 volts respectively. The $1\mu \times 4\mu$ Schottky diodes have cut-off frequencies of 1.4THz and breakdown voltage of 8 volts. To determine the switching speed, a 16 stage ECL ring oscillator (the 9th stage was configured non-inverting) was built using $3\mu \times 10\mu$ HBTs. A photograph of the ring oscillator is shown in Fig.4 and the output waveform as measured by a Tektronix CSA 803 oscilloscope is shown in Fig.5.

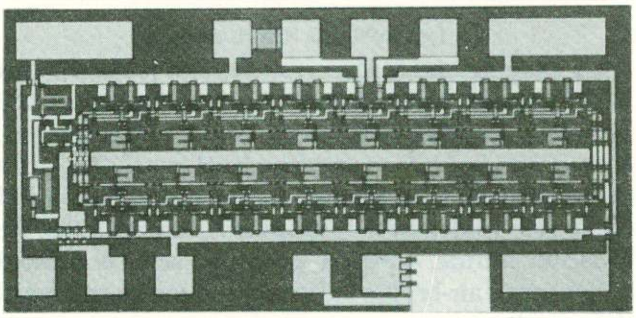

Fig.4. Photograph of the ring oscillator.

From the oscillation frequency of 1.097GHz, we obtain a gate delay of 28.49ps. The circuit consists of 82 transistors (5 per stage + 2 for the current source) and over 600 contact vias.

PRESCALER DESIGN

The prescaler was designed for increasing the triggering bandwidth of Tektronix oscilloscopes. At the present time, the maximum direct trigger frequency is limited to 2.5GHz. Since the prescaler has to be used in an oscilloscope, the input sensitivity has to be increased by a preamplifier. An two stage differential amplifier with 30dB gain and a 3dB bandwidth of approximately 8GHz was designed. This has a useful bandwidth up to 12GHz. The preamplifier uses inductive peaking to

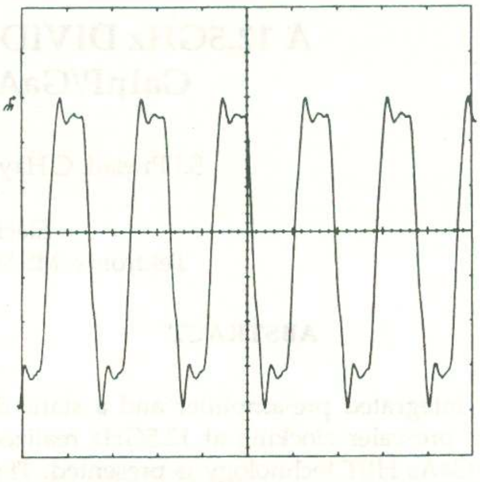

Fig.5. Typical ring oscillator output waveform.
X axis: 500ps/div, Y axis: 10mV/div F_{osc}=1.097GHz.

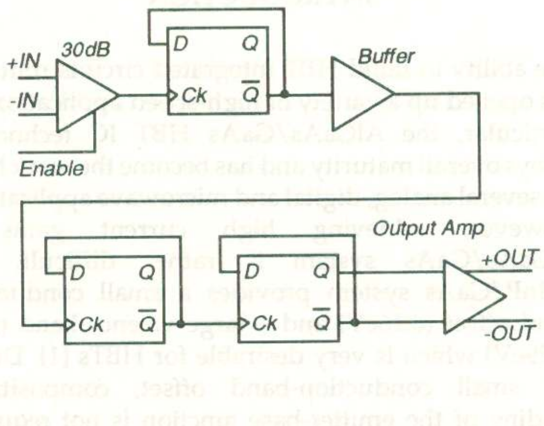

Fig.6. Block diagram of the prescaler.

achieve this bandwidth making use of the air-bridge inductors in the process. The preamplifier is DC coupled at the input and provides a differential output. The output is back terminated in 50 ohms. A separate enable input is provided to prevent unwanted signals from triggering the scope when the prescaler is not in use. The preamplifier is followed by three D flip-flops each of which is composed of two latches. A complete block diagram of the prescaler is shown in Fig.6. A buffer is used immediately after the first D flip-flop to prevent loading and maintain speed. A final output amplifier provides differential output and triggers the scope. Most of the circuitry is ECL and operates from +3V and -5V. The circuit has 111 transistors and most of them have an emitter size of $3\mu \times 7\mu$ operating at a collector current of 3-6mA. A 5V to 3V power supply was also designed so that the circuit can operate from ±5V.

RESULTS

The complete prescaler and power supply chip photograph is shown in Fig.7. The die size is 76x52mils. The circuit dissipates 1.5Watts and about 0.9Watt is dissipated in the internal 5V to 3V power supply. The input and output waveforms are shown in Fig.8. The circuit performs satisfactorily up to 12.5GHz. The input sensitivity at 12.5GHz is 120mV peak-to-peak. An important specification for this circuit is the time jitter introduced between input and output. The combined rms jitter of the scope and the prescaler was found to be less than 2ps.

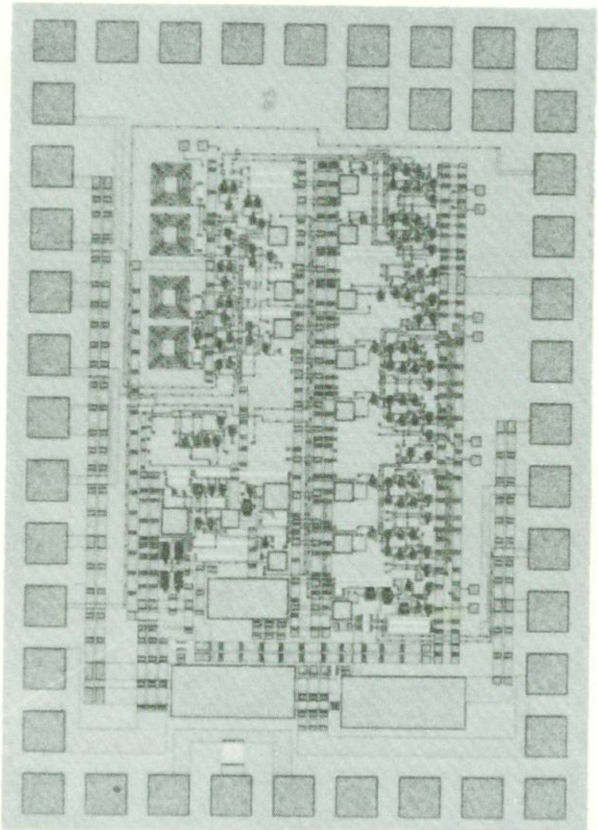

Fig.7. Die photograph of the prescaler.

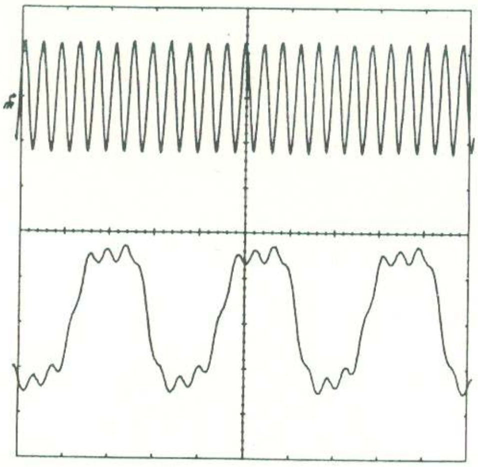

Fig.8. Prescaler waveforms.
X axis: 200ps/div, Y axis: 50mV/div
Top Trace: Input at 12.5GHz
Bottom Trace: Output at 1.563GHz

CONCLUSION

We have successfully demonstrated a GaInP/GaAs HBT IC technology with 60GHz-f_T and 45GHz-f_{max}. Unloaded ECL gate delays of 28ps have been measured. A fully integrated pre-amplfier and static divide-by-eight circuit clocks up to 12.5GHz.

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REFERENCES

1. S.J.Prasad et al.,"35GHz Ft and 26GHz Fmax GaInP/GaAs Heterojunction Bipolar Transistors", Electronics Letters, 28(5), pp.2341-2343, 1992.
2. T.Lauterbach et al.,"GaAs Bipolar Transistors with GaInP Hole Barrier and Carbon-doped base grown by OMVPE", IEEE Transactions on Electron Devices, 39(4), pp.753-756, 1992.