

ELECTRIC FIELD DEPENDENCY OF TRAPS IN MESFET/HEMT DEVICES

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ABSTRACT

A new measurement procedure for observing the dependence of the frequency dispersion effect on electric field for GaAs MESFET/HEMT devices is presented. The new procedure employs a statistically based pulse I/V measurement system for observing the memory effect in these devices. The results indicate, possibly for the first time, the true extent of the effects of the traps in these devices.

INTRODUCTION

In this paper, a new pulsed I/V measurement technique for observing the dependence of the frequency dispersion effect on electric field for GaAs devices is presented. The results obtained with the new procedure are compared with experimental data obtained with conventional pulsed and static IV characterisation systems. The results indicate that the effect of the trapping states is more serious than has hitherto been thought.

MEASUREMENTS AND DEVICES

The measurement system employed to investigate the frequency dispersion or hysteresis effect in GaAs devices is shown in Figure 1, Fernandez et al(1). For the purposes of this paper the most relevant measurements performed with this system were:

- (i) Static IV measurements: These were performed with a very slow sweep rate (1 second/point) to emphasise the self-heating effect as much as possible.
- (ii) Pulsed IV measurements: These were performed by pulsing the gate-source and drain-source terminals from the static position of $V_{gs}=-1V$ and $V_{ds}=0V$. Since the pulse widths employed were of $1\mu s$ width (with a rise and fall-time of 50ns) with a period of 1ms, the self-heating effect is not relevant, Teyssier et al (2), Parker et al (3) and Rodriguez et al (4).
- (iii) Pseudo-random pulsed IV measurements: A clearer understanding of this new measurement procedure can be obtained by considering Figure 2. For this case the static supplies are set to $V_{DS}=0V$, $V_{GS}=-1V$ and the drain current at the dynamic bias point of $v_{ds}=3V$ $v_{gs}=0V$ is to be measured. The drain current at this point is measured by firstly launching a pulse whose base potential is the static value and whose final amplitude is a pseudo-random value. If the gate and drain terminals of the device are to be pulsed then clearly two such independent pulses would be required. The amplitude of the pulses denoted as $v_{ds\ random}$ and $v_{gs\ random}$ is determined using a pseudo-random algorithm. After $1\mu s$ another pulse is launched whose base potential is the pseudo-random value and the final value the desired point to be measured. As far as the dynamic point to be measured is concerned, the origin of the pulses are not, therefore, fixed at the static point but vary in an unpredictable manner. Furthermore, because the pulse widths are narrow, no self-heating effects are introduced. Once the value of the drain current is noted, the pulse amplitude returns to the static conditions. The drain current at the same dynamic point is then measured again, using different pseudo-random values. If this process is repeated a

large number of times (say 1000), then an accurate appreciation of the hysteresis effect can be obtained.

To demonstrate the results, a 4 finger 225 μ m gate-width/finger MESFET device with a pinch-off voltage of -0.8V from GEC Marconi Materials Research Ltd will be used as a demonstrator.

EXPERIMENTAL RESULTS

In Figure 3 we compare the drain current of the device when measured with the pseudo-random method, the normal dc method, and the normal pulsed method for the $V_{gs}=-0.4V$ curve. For the normal pulsed method, the static bias point corresponds to $V_{DS}=0V$ $V_{GS}=-1V$. For the normal dc method, a one second settling time was used. In a previous article[4] it was clearly shown that the differences between the pulsed (normal) and dc IV characteristics of the device were not entirely due to thermal but frequency dispersion effects. The pseudo-random data presented here re-enforces this point and shows that the memory effect is more serious than may have been thought. Notice, for example, that the pseudo-random data produces excursions on the drain current which fall outside of the range of values provided by the conventional measurements.

This effect is not, of course, restricted to the saturation region. In Figure 4, for example, we show the drain current as a function of the pseudo-random drain source voltage for different drain-source destination values at $v_{gs}=0V$. As can be seen in the linear region, the dependency of the traps on electric field is just as relevant as in the saturation region. Since these results indicate a large charge storage effect occurring in the device at low frequencies, the data of Figure 4 can be represented as a conventional capacitance-voltage graph, as is shown in Figure 5 using log scales. These results were computed using a switching time constant of 50ns, which corresponds to the rise and fall-time of the measurement system employed. This capacitance data corresponds to a measurement frequency of 1KHz. Independent capacitance measurement on the device using a 1KHz sinewave generator and oscilloscope confirmed the above capacitance values.

SUMMARY/CONCLUSIONS

A new experimental system for observing the dependence of the memory effect in GaAs devices on electric field has been presented and compared with conventional measurements. The results indicate a much larger change in the device IV characteristics due to trapping effects than previously thought. This behaviour is true in the saturation and linear regions of operation.

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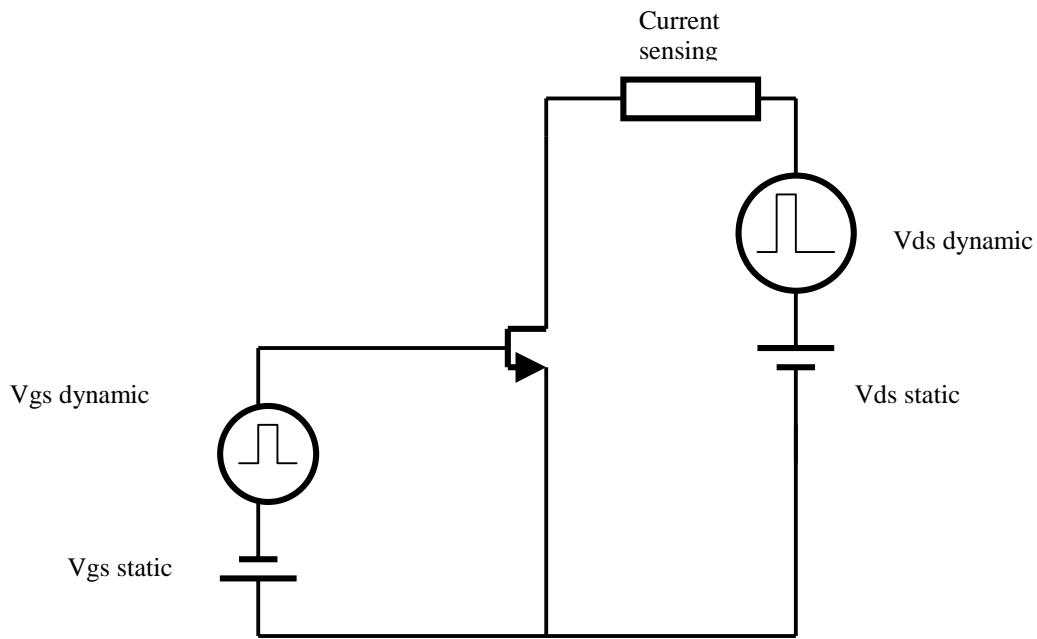


Figure 1. Pulse I/V Measurement System

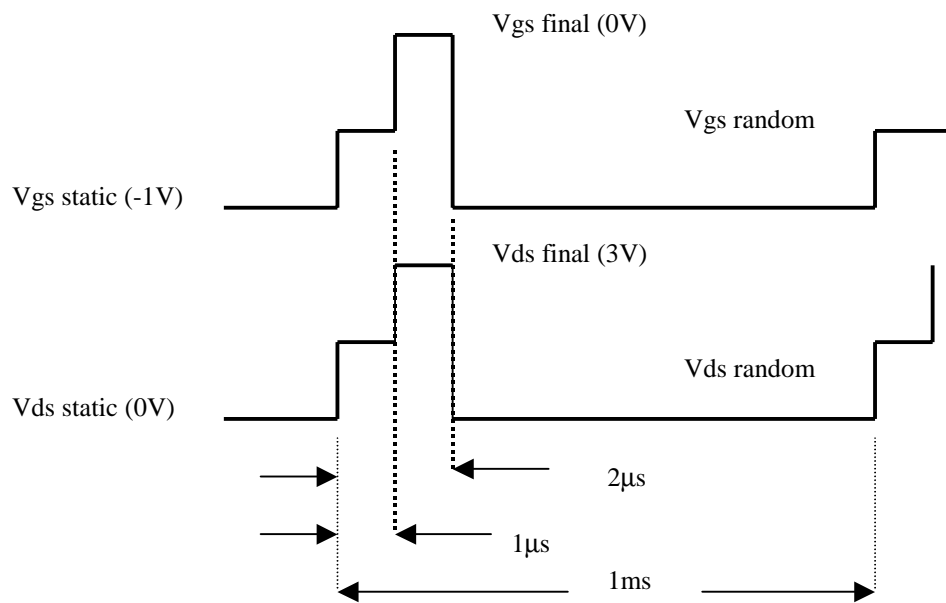


Figure 2. Pseudo-random Pulse Sequence

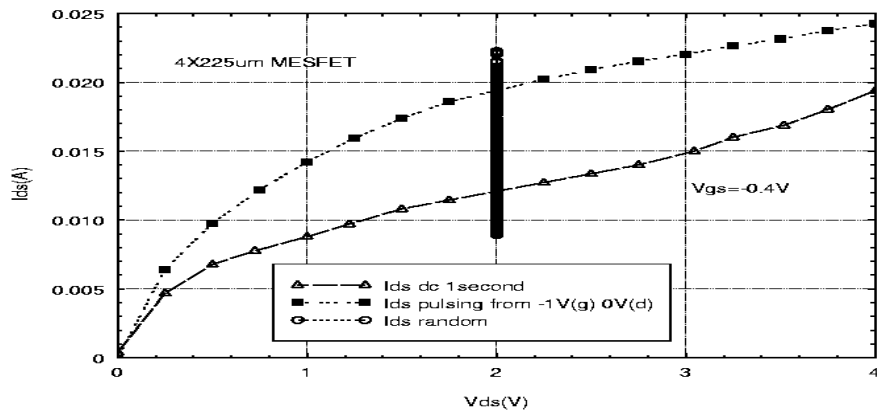


Figure 3. Comparison of I_{ds} at $V_{ds}=2V$, $V_{gs}=-0.4V$

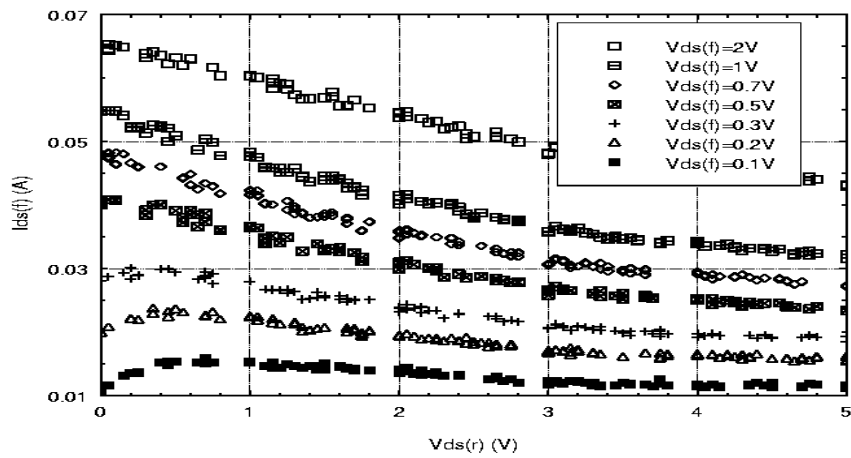


Figure 4. I_{ds} vs pseudo-random V_{ds} for different V_{ds} destination values @ $V_{gs}=0V$

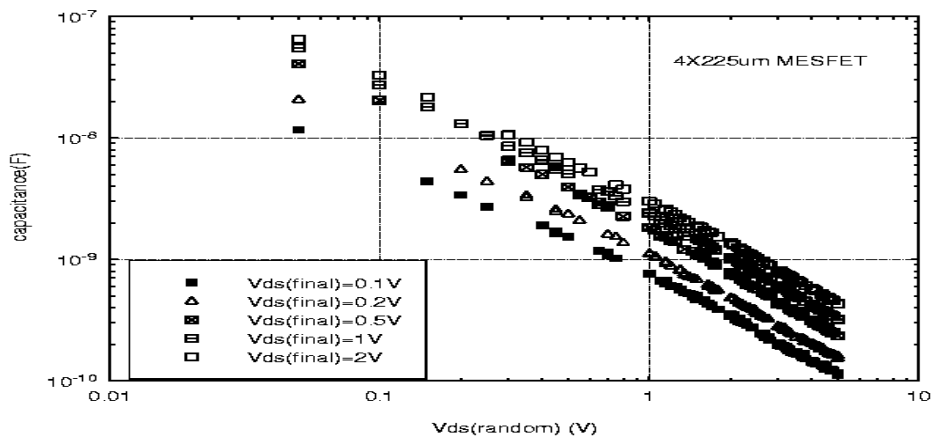


Figure 5. Calculated capacitance using pseudo-random data with a switching time of 50ns