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High-Gain and High-Bandwidth AlGaN/GaN HEMT Comparator

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1. Introduction

AlGaN/GaN HEMT technology is emerging as a promising candidate for next-generation power switches owing to their superior performance including high breakdown voltage, low on-resistance, high switching speed, and high temperature operation. To develop fully integrated power integrated circuits that also include the gate drive, sensing and control functions, digital and analog mixed-signal building blocks need to be developed [1]. Voltage comparator is an important building block for many mixed-signal ICs including analog-to-digital converters, operational amplifiers, and control circuits of DC-DC converters. The ac voltage gain and bandwidth of voltage comparators have been studied in various material systems, including silicon [2], [3], gallium arsenide [4], [5], and silicon carbide [6], [7]. These works are summarized in Table 1.

For GaN-based comparator, however, there has been no report on the dynamic response. In this paper, high-gain and high-bandwidth AlGaN/GaN HEMT voltage comparator was presented based on detailed characterization from room temperature to 250^0C.

2. Experimental Setup and Results Discussion

The circuit layout is the same as that presented in [1]. A photograph of the fabricated comparator is shown in Fig. 1, along with the schematic circuit diagram. M1 and M2 are two identical enhancement-mode HEMTs (with a gate length L_g of 1.5µm, and a gate width W_g of 60µm). Depletion-mode HEMTs M3 and M4 (L_g= 4µm, W_g = 8µm) act as active loads. Depletion-mode HEMT M5 (L_g= 1.5µm, W_g = 90µm) is a current source.

The dc transfer characteristic of the voltage comparator was measured with a V_{DD} of 10V. V_{ref} was fixed at a value between 0.5V and 2V, in 0.5V step. V_{in} was swept between 0V and 3V. The measurement was conducted at different temperatures, and V_{bias} was finely tuned to support the current re-distribution through the two branches during the transition. The transfer characteristics (V_{out} vs. V_{in}) are plotted in Fig. 2. The transition region remains sharp even at 250^0C. This implies negligible degradation of small signal gain at high temperatures. The transition at the preset V_{ref} also reveals a good matching of the transistor pair and insignificant input offset.

Table 1. Summary of voltage comparator related circuit performance in different material systems at various temperatures. UGF: unity gain frequency

Author	Yr.	Tech.	Circuit	Gain (dB)		UGF(MHz)	
				25^0C	200^0C	25^0C	200^0C
J.D.Beasom *et al.* [2]	1982	Si BJT	2 stage op-amp	96	92	11.9	8.1
I.G.Finvers *et al.* [3]	1995	CMOS	2 stage op-amp	72	-	3.3	2.2
G.Schweeger *et al.* [4]	1991	GaAs MESFET	Comparator, resistive load	~9.5	~9.3	~3.5	~3.1
K. Fricke *et al.* [5]	1994	AlGaAs/ GaAs HBT	2 stage op-amp	49.5	35.8	-	-
M.Tomana *et al.* [6]	1993	6H-SiC MESFET	2 stage op-amp	65.5	64.4	1.08	1.10
A.C. Patil *et al.* [7]	2009	6H-SiC JFET	Comparator, resistive load	~28	~16 (450^0C)	~0.8	~0.3 (450^0C)

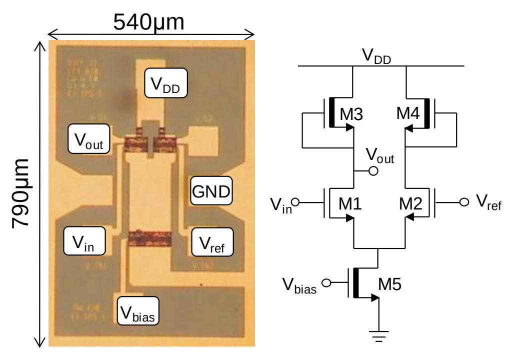

Fig. 1. Photograph of AlGaN/GaN comparator chip. The chip size is approximately 790 × 540µm.

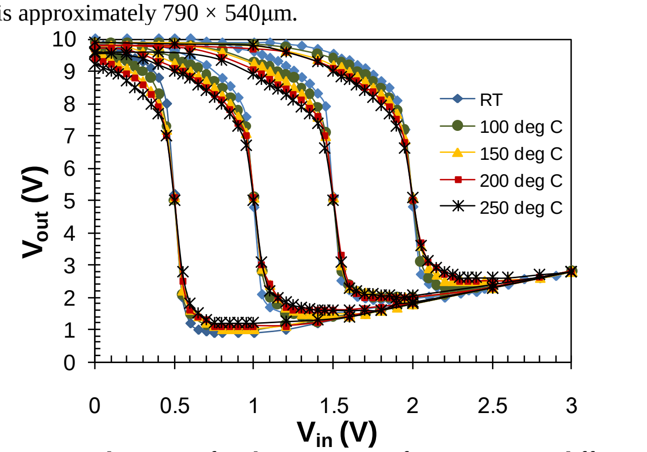

Fig. 2. Voltage transfer characteristics of comparator at different V_{ref} over a wide range of temperatures.

To characterize the comparator's small signal response, we fix V_{DD} at 10V and V_{ref} at 0.5V. V_{in} includes a small sinusoidal signal ($V_{p\text{-}p}$=30mV) plus a dc bias voltage the same as V_{ref}. V_{out} was measured with a high impedance probe to avoid the loading effect. Voltage gain V_{out}/V_{in} was obtained from 30 KHz to 100 MHz at various temperatures (from 25 ^{0}C to 250 ^{0}C).

The AlGaN/GaN HEMT comparator's performance is summarized in Fig. 3. The trend of the small signal gain over the temperature is consistent with the slope at transitions of transfer curves shown in Fig. 1. The unity-gain frequency (UGF) is 310MHz at 25^{0}C and 149MHz at 250^{0}C, significantly higher than those reported in other technologies (table I). The high UGF is attributed to the high switching frequency of the AlGaN/GaN HEMT. The 3-dB bandwidth is 5.5MHz at 25^{0}C and 3.9MHz at 250^{0}C.

The AlGaN/GaN HEMT comparator's large signal response was also measured. With V_{DD} at 10V and V_{ref} at 500mV, V_{in} was driven with a 1V square-wave. Fig. 4 shows the comparator response with a V_{in} oscillating at 1MHz. The propagation delay time, the rise/fall time (t_{pd+}/ t_{pd-}) are plotted in Fig. 5, with all three exhibiting a rising trend with increasing temperature.

3. Conclusion

The dynamic response of AlGaN/GaN HEMT voltage comparator was characterized. This comparator with active load demonstrates superior performance of high gain (>31dB) and wide bandwidth (>4MHz), and small propagation delay time (<20ns) over a wide range of temperatures up to 250^{0}C.

Acknowledgment

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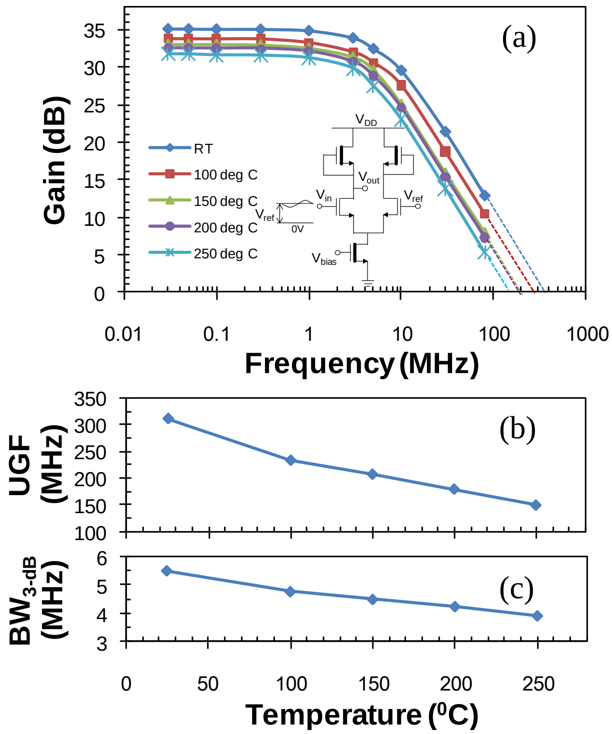

Fig. 3. Measured (a) small signal voltage gain of the comparator, the extracted (b) unity gain frequency (UGF), and (c) 3-dB bandwidth ($BW_{3\text{-dB}}$) at various temperatures.

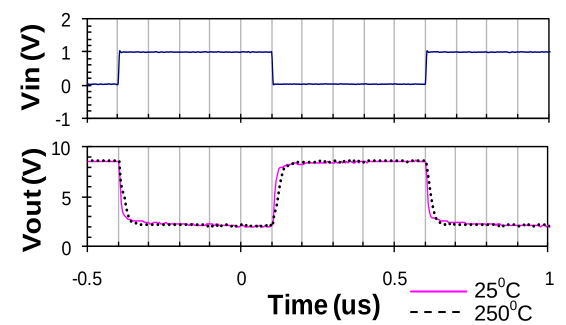

Fig. 4. The timing diagram of 1MHz large square pulse input and the voltage comparator output response.

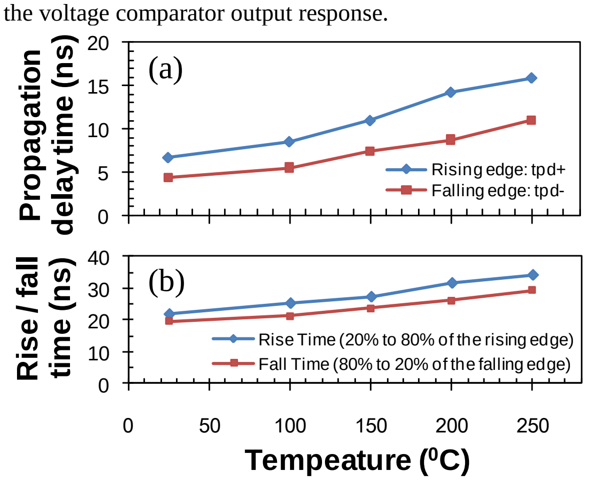

Fig. 5. Measured (a) propagation delay time, and (b) rise time and fall time of the voltage comparator under the 1V large input voltage step at various temperatures.