

Highly Integrated Intelligent Power Transistor Driver, Isolated Data Transceiver, and Versatile PWM Controller Circuits for High Temperature and High Reliability Power Applications

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ABSTRACT

In this paper we present a set of integrated circuits specifically designed for high temperature power applications such as isolated power transistor drivers and high efficiency power supplies.

The XTR26010 is the key circuit for the isolated power gate drive application. The XTR26010 circuit has been designed with a high focus in offering a robust, reliable and efficient solution for driving a large variety of high-temperature, high-voltage, and high-efficiency power transistors (SiC, GaN, Si) existing in the market. The XTR40010 is used for isolated data communication between a microcontroller or a PWM controller and the power driver (XTR26010). The isolated power transistor driver features a dual turn-on channel, a turn-off channel and a Miller Clamp channel with more than 3A peak current drive strength for each channel. The dV/dt immunity between XTR26010 and XTR40010 exceeds 50kV/μs.

To demonstrate the performance and reliability at system level, a half-bridge driver test-board has been developed for driving SiC MOSFETs. For supplying this test-board, a compact isolated flyback power supply with 82% power efficiency has been developed thanks to the versatile voltage mode PWM controller XTR30010 and the XT2N0825 N-Channel MOSFET.

The full system including an isolated half-bridge gate driver and associated isolated power supply has been successfully tested up to 200°C, up to 600kHz of switching frequency and 600V high-voltage bus. The 200°C limitation is due to passives, PCB material, and the solder paste used for the test board. However, all used X-REL active circuits have been qualified within specifications well above 230°C.

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INTRODUCTION

Power systems are continuously looking for high efficiency systems especially for high temperature applications where self-heating margin is very small. In applications such as Intelligent Power Modules (IPM), Motor Drives, and Power Inverters, high efficiency, high voltage and high temperature Silicon Carbide (SiC) and Gallium Nitride (GaN) power transistors are being used in several industries including aerospace, automotive, industrial and down-hole. In this paper, we present a highly integrated, high-temperature solution for driving such power transistors. The solution is based on the XTR26010 (High-Temperature Intelligent Gate Driver) with the XTR40010 (High-Temperature Isolated Two Channel Transceiver) for isolated gate drive, and XTR30010 (High-

Temperature PWM Controller) with XTR2N0825 (High-Temperature 80V N-Channel Power MOSFET) for isolated power supply.

In the following sections, we first present the operation and features of the XTR26010 and XTR40010. Then, the half bridge driver test-board based on XTR26010 and XTR40010 is presented. Next, the flyback power supply based on XTR30010 and XTR2N0825 is presented with measured performance. Finally, measurements results of the full system showing functionality at 200°C, at frequency up to 600kHz are presented.

In the following sections, "temperature" refers to "ambient temperature".

HIGH-TEMPERATURE INTELLIGENT GATE DRIVER: XTR26010

The XTR26010 is a high-temperature, high reliability isolated power transistor driver integrated circuit, able to drive a large variety of high-temperature, high-voltage, and high-efficiency power transistors. XTR26010 is able to drive normally-On and normally-Off power transistors in Silicon Carbide (SiC), Gallium Nitride (GaN) and standard silicon, including JFETs, MOSFETs, BJTs, SJTs and MESFETs.

The XTR26010 circuit includes an internal voltage regulator, a 5-channel transceiver (2 TX and 3 RX) for isolated data transmission with the microcontroller and between high side and low side drivers. To turn on some normally-off power transistors, the XTR26010 includes two independent pull-up gate-drive-channels (PU_DR1 and PU_DR2) capable of sourcing a typical 3A peak current, with a programmable pulse-width for DR1 channel. The XTR26010 includes two pull-down gate-drive-channels capable of sinking a typical 3A peak current (PD_DR and PD_MC). The PD_DR channel is used for the effective turn-off of the power transistor, while PD_MC channel is used for Active Miller Clamping (AMC) function thanks to its capacitor-programmable delay versus PD_DR channel. Figure 1 shows a simplified block diagram of the XTR26010.

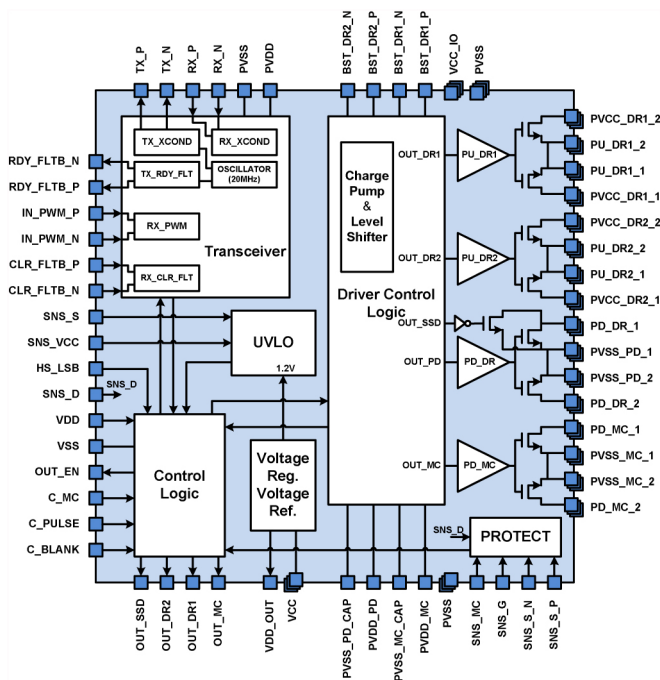


Figure 1. Block diagram of XTR26010 circuit.

In addition, the XTR26010 circuit implements an unprecedented functionality for high-temperature drivers allowing safe operation at system level by preventing any cross-conduction between high-side and low-side switches, through isolated communication between high-side and low-side drivers. The circuit also includes programmable Under Voltage Lockout (UVLO) and soft shut-

down capability that slowly shuts down the power transistor in case of fault. The XTR26010 is able to detect failures on the drain, gate and source of the power switch. In addition, safe start-up and cross-conduction protection are implemented to guarantee safe operation at system level.

The XTR26010 can be used standalone but also as a controller with multiplied drive capabilities using the XTR25010, which is equivalent to the output section of the XTR26010. More details can be found in the XTR26010 datasheet [1]

Figure 2 and Figure 3 show the measured propagation delay from the PWM inputs to the driver outputs versus temperature. It is seen that the propagation delay increases by less than 100ns from 25°C to 230°C. Figure 4 shows the peak output current capabilities of the XTR26010. At 25°C the peak output current reaches 3A and stays higher than 2A at 230°C for the each pull-up driver.

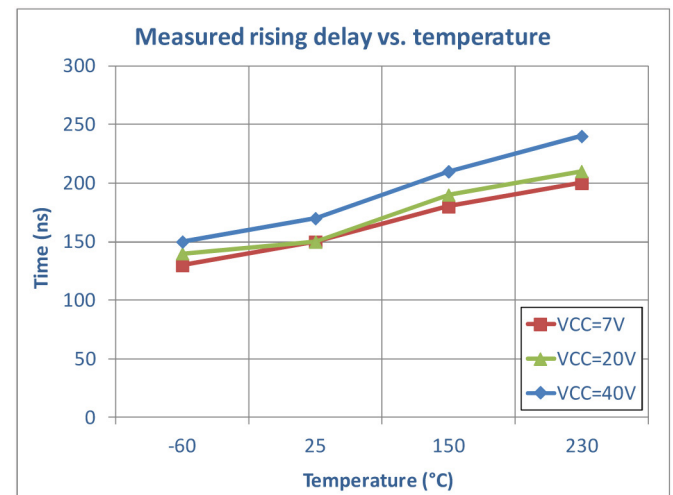


Figure 2. Measured propagation delay for rising edge of XTR26010 versus temperature.

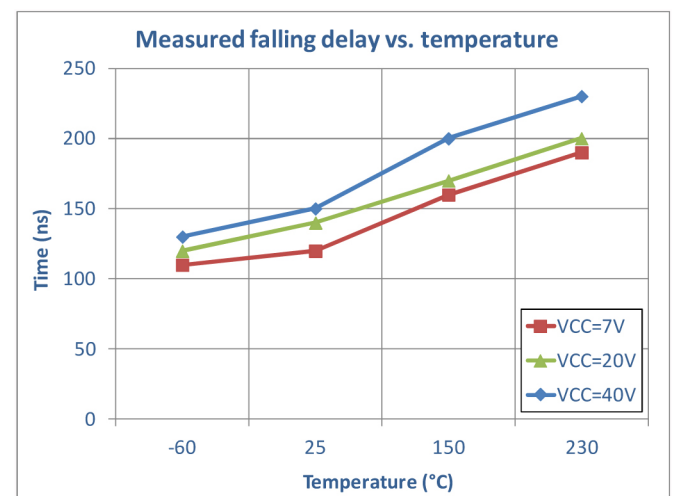


Figure 3. Measured propagation delay for falling edge of XTR26010 versus temperature.

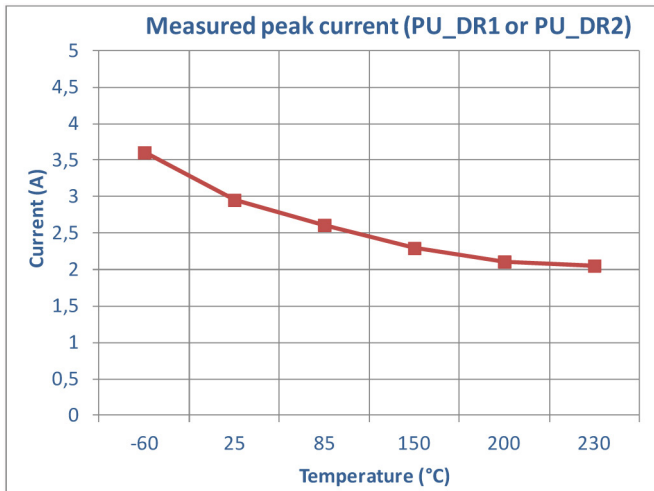


Figure 4. Measured output current of XTR26010 (turn-on).

HIGH-TEMPERATURE ISOLATED TWO CHANNEL TRANSCEIVER: XTR40010

The XTR40010 implements a high-temperature dual-channel (2 TX/RX) isolated data transceiver. It can be used as general purpose isolated transceiver. It is also well suited for isolated data communication between a microcontroller or a PWM controller, with the intelligent power gate driver XTR26010. The galvanic isolation is achieved by external high-temperature 1:1 pulse transformers.

The XTR40010 integrates in a single package double full duplex transceiver. The implementation of the two full duplex TX/RX isolated channels requires two XTR40010, one on each side of the pulse transformers. When used with XTR26010, the XTR40010 allows implementing two full duplex TX/RX channels with only one instance of XTR26010. Indeed, the XTR26010 transceiver is fully compatible with the XTR40010. The complete solution is optimized to minimize the size of the transformer, the number of external components, the transmission delay (<120ns) and to maximize the noise margin, even in harsh dV/dt conditions (50kV/μs across 2pF of inter-winding capacitance).

Figure 5 shows a simplified block diagram of the XTR40010. More details can be found in the XTR40010 datasheet [2].

Figure 6 shows the current consumption of the XTR40010 with both input receiving a 1MHz, 50% duty cycle signal and 50pF output capacitance at each output. It is seen that the current consumption stays below 25mA for 100% duty-cycle, with very low variation across temperature and below 100μA in standby mode.

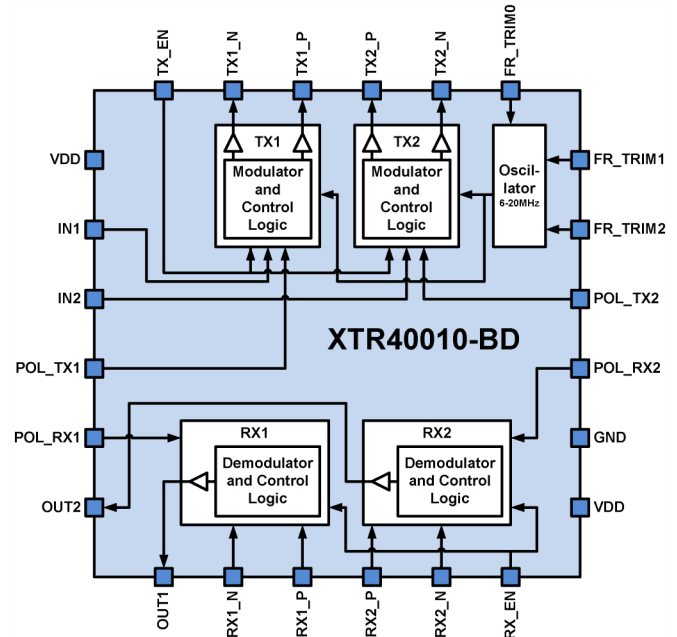


Figure 5. Block diagram of XTR40010.

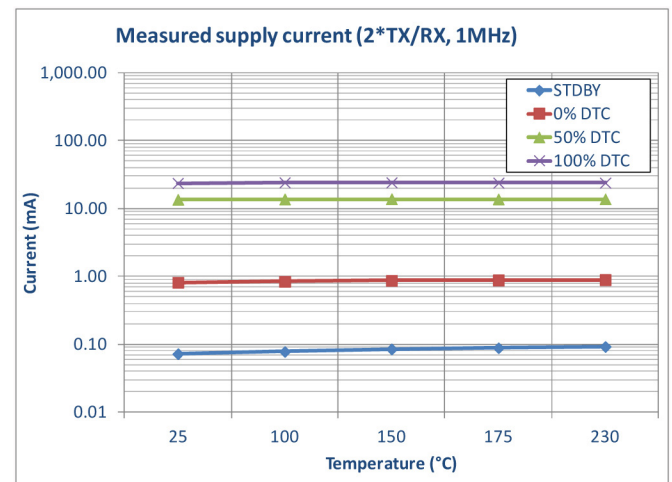


Figure 6. Measured current consumption of XTR40010.

Figure 7 presents oscilloscope traces showing the input signal (in yellow), the modulated signal applied to the pulse transformer primary (in magenta), the received signal on the secondary (in green), and the output signal (in red). The typical propagation delay is around 120ns. The pulse transformer used here is perfectly symmetrical (1:1). No transformation gain is needed to compensate the losses in the transformer thanks to the efficient demodulation protocol used in XTR40010.