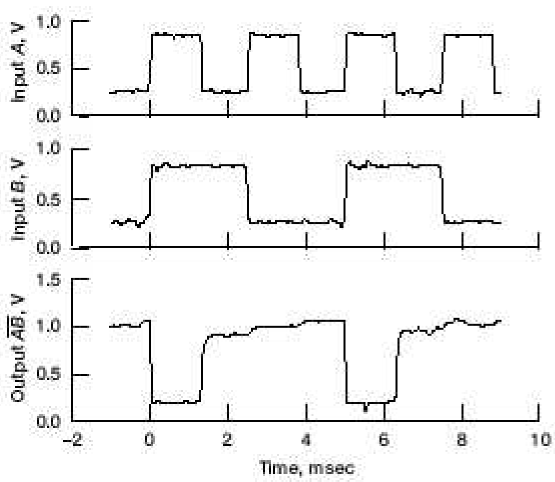
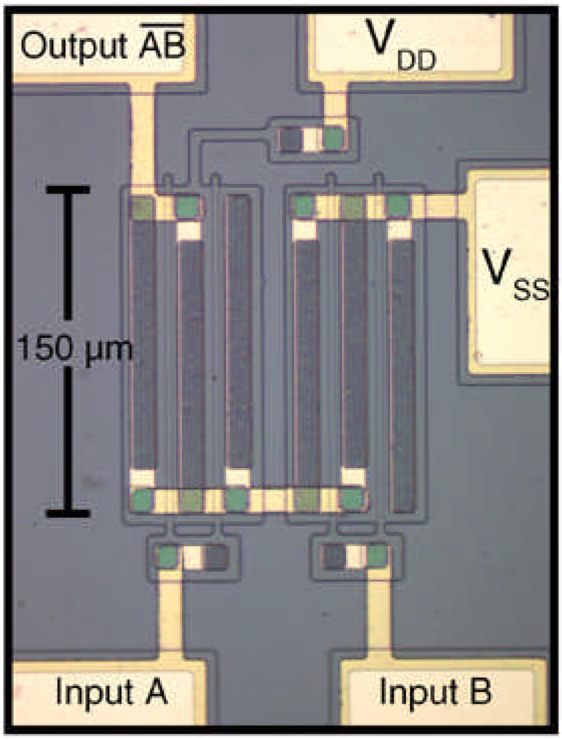
Silicon Carbide Junction Field Effect Transistor Digital Logic Gates Demonstrated at 600 °C

Complex electronics and sensors are increasingly being relied on to enhance the capabilities and efficiency of modern jet aircraft. Many of these electronics and sensors monitor and control vital engine components and aerosurfaces that operate at high temperatures. However, since today's silicon-based electronics technology cannot function at high temperatures, these electronics must reside in environmentally controlled areas. This necessitates either the use of long wire runs between sheltered electronics and hot-area sensors and controls, or the fuel cooling of electronics and sensors located in high-temperature areas. Both of these low-temperature-electronics approaches suffer from serious drawbacks in terms of increased weight, decreased fuel efficiency, and reduction of aircraft reliability. A family of high-temperature electronics and sensors that could function in hot areas would enable substantial aircraft performance gains. Especially since, in the future, some turbine-engine electronics may need to function at temperatures as high as 600 °C.



600 °C NAND gate, consisting of two SiC JFET's and a resistor. Signal input and output pads are labeled, along with the V_{DD} and V_{SS} bonding pads that supply power to the circuit.

The High Temperature Integrated Electronics and Sensors (HTIES) Program at the NASA Lewis Research Center is currently developing silicon carbide (SiC) for use in harsh conditions where silicon, the semiconductor used in nearly all of today's electronics, cannot function. The HTIES team recently fabricated and demonstrated the first semiconductor digital logic gates ever to function at 600 °C. The photomicrograph shows a NAND (not *A* and not *B*) logic gate, consisting of two junction field effect transistors (JFET's) and a resistor fabricated in epitaxially grown SiC. The graph shows operational waveforms of the SiC NAND gate collected on a probing station when the sample was heated to a glowing, red-hot 600 °C. The input voltage waveforms are shown across the top, and the logic gate waveform output voltage is shown on the bottom. On all the waveforms, a binary logic zero is represented by a voltage of 0.25 V or less, whereas a voltage of 0.85 V or higher corresponds to a binary logic one. Whenever one of the inputs is a logic zero (0.25 V), the output of the logic gate is greater than 0.9 V (a logic one); only when two logic ones are input does the logic gate output drop to 0.2 V (a logic zero), consistent with the NAND binary logic function. In addition to the NAND gates, NOT (not *A*) and NOR (not *A* or not *B*) gates on the same SiC wafer demonstrated successful 600 °C operation.



Operational waveforms demonstrating the 600 °C functionality of the SiC NAND gate.

Demonstration of simple logic functions at 600 °C represents a measurable step forward. Nevertheless, many further advancements are necessary before SiC electronics will be ready for reliable long-term operation at extreme temperatures. These necessary advancements include increased circuit complexity, demonstration of long-term operation, and development of high-temperature electronics packaging and connectors.

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