A Power Electronics Application

1) Power switches;
2) Drivers;
3) Sensing circuit
4) Microcontroller
Power semiconductors devices

- **Silicon**
  - Diodes
    - Schottky
    - Epitaxial (PIN)
    - Double diffusion (PIN)
  - Transistors
    - NPN
    - PNP
    - MOSFET
      - N-channel
        - Conventional
        - Super junction
        - CoolMOS
      - P-channel
  - Thyristors
    - Fast thyristors
    - Symmetric
    - Asymmetric
    - Reverse
  - NPN BJT
  - DMOSFET
  - JFET
  - IGCT
  - MCT
  - N-type
  - P-type
  - MTO

- **Silicon Carbide**
  - Diodes
  - Transistors
  - Thyristors

- **Gallium Nitride**
  - Diodes
  - Transistors
Table 1. Physical properties for various semiconductors.

<table>
<thead>
<tr>
<th>Material</th>
<th>$E_G$, eV</th>
<th>$E_C$, MV/cm</th>
<th>$n_i$, cm$^{-3}$</th>
<th>$\varepsilon_r$</th>
<th>$\mu_r$, cm$^2$/V/s</th>
<th>$v_{SAT}$, $10^7$ cm/s</th>
<th>$\sigma_T$, W/m/K</th>
<th>CTE, ppm/K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>1.1</td>
<td>0.3</td>
<td>$10^{10}$</td>
<td>11.9</td>
<td>1400</td>
<td>1.02</td>
<td>130</td>
<td>2.6</td>
</tr>
<tr>
<td>GaAs</td>
<td>1.424</td>
<td>0.4</td>
<td>$2.1 \times 10^6$</td>
<td>13.1</td>
<td>8500</td>
<td>2.0</td>
<td>55</td>
<td>5.73</td>
</tr>
<tr>
<td>3C-SiC</td>
<td>2.36</td>
<td>1</td>
<td>10</td>
<td>$\leq 800$</td>
<td>2.0</td>
<td>360</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td>4H-SiC</td>
<td>3.23</td>
<td>3-5</td>
<td>$8.2 \times 10^{-9}$</td>
<td>10.1</td>
<td>$\leq 900$</td>
<td>2.0</td>
<td>370</td>
<td>5.12</td>
</tr>
<tr>
<td>6H-SiC</td>
<td>3.0</td>
<td>3-5</td>
<td>$2.3 \times 10^{-6}$</td>
<td>9.66</td>
<td>$\leq 400$</td>
<td>2.0</td>
<td>490</td>
<td>4.3-4.7</td>
</tr>
<tr>
<td>GaN wurtzite</td>
<td>3.39</td>
<td>3-5</td>
<td>$1.9 \times 10^{-10}$</td>
<td>9</td>
<td>$\leq 1000$</td>
<td>2.2</td>
<td>130</td>
<td>3.2-5.6</td>
</tr>
<tr>
<td>GaN zinc blende</td>
<td>3.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diamond</td>
<td>5.45</td>
<td>5.6</td>
<td>$1.6 \times 10^{-27}$</td>
<td>5.5</td>
<td>1900</td>
<td>2.7</td>
<td>600-2,000</td>
<td>0.8</td>
</tr>
</tbody>
</table>

\[
R_{SP-ON} = \frac{1.716 \times 10^{-6} \varepsilon_r B V^{2.5} E_{G}^{-3}}{\mu_n}
\]
\[
R_{SP-ON} = \frac{3.351 \times 10^{-3} B V^2 E_{G}^{-6}}{\varepsilon_r \mu_n}
\]
\[
R_{SP-ON} = \frac{8.725 \times 10^{-3} B V^2 E_{G}^{-7.5}}{\varepsilon_r \mu_n}
\]
A Performance Comparison of GaN E-HEMTs Versus SiC MOSFETs in Power Switching Applications, Jason (Jianchun) Xu, Di Chen, GaN Systems Inc

A 50-kW High-Frequency and High-Efficiency SiC Voltage Source Inverter for More Electric Aircraft, Shan Yin, King Jet Tseng; Rejeki Simanjorang; Yong Liu; Josep Pou
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Gate drivers

Some Features
- Working voltage 1200 V isolated driver
- 2.5 A peak output current
- 3.75 kV$_{rms}$ isolating voltage
- <50 kV/µs common-mode transient immunity
- > 100 ns propagation delay
- Integrated IGBT protections:
  - Soft turn-off
  - Desaturation detection (DESAT)
  - Active Miller-Current clamp
  - High Side undervoltage lockout (UVLO) protection with feedback
  - Fault sensing/reporting to system controller (DESAT & UVLO)

Typical application configuration of Solantro SA6880-S gate driver
High peak output driver current → Fast switching → Low losses → High switching frequency
DESAT with soft shutdown
DESAT with soft shutdown
Miller Clamp
High **gate source voltage** → Fast switching → Low losses → High switching frequency

Low **gate source voltage** → Slow switching → High losses → High temperature → Destroy switch
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An example of current sense circuit
Some Features of Solantro CSA

- ±250 mV input voltage range optimized for shunt resistors
- Very low nonlinearity: 0.075% maximum
- Low input offset voltage: 200 µV typical
- Low noise: 3.1 µVrms typical
- Delay: 350 ns/700 ns
- Input bandwidth: 500 kHz typical
- Nominal gain: 8 (gain error ±0.5%)
- 100 V/ns transient dv/dt immunity
- High common-mode rejection ratio: 70 dB
- 3.3 V operation on both high-side and low-side
- Certified galvanic isolation
  - UL1577 and IEC60747-5-2
  - isolation voltage: 5000 Vrms for 60 s
  - working voltage: ±1000 V
- Operating temperature range -40°C to 125°C
Bandwidth

FICS amplifier normalized output voltage in function of frequency
Circuit for testing Common mode immunity
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Rich power control-centric analog Peripherals:
- Sixteen-channel, 10-bit, 1.4 MS/s ADC
- 2 four-channel, 10-bit, 1.4 MS/s ADC
- 17 10 ns fast comparators
- 24 10-bit analog DACs for internal comparator threshold settings
- Two differential high-speed current sensing amplifier interfaces
- Programmable anti-alias low-pass filters
- Temperature sensing

Digital Power Engine and Peripherals:
- 32-bit RISC CPU with 64 KiB RAM
- 256 KiB internal SPI flash memory
- Switching engine for up to 8 drivers with gate control for cross-conduction protection
- Four event-driven timing engines with sixteen event processing channels for hysteresis control.
- Four PWM timers (10ns resolution, 625ps fractional)
- Up to four interleaved timers with real-time programmable phase shift (any phase shift) with 10ns resolution
- Dedicated high-performance digital AC PLL with a dedicated sensing comparator for grid synchronization
- Simultaneous adjustable real-time update of frequency and duty cycle.

Junction temperature - 40 to 125\degree C.
Switching Engine
Hysteretic control

![Hysteretic control diagram]
Thank you