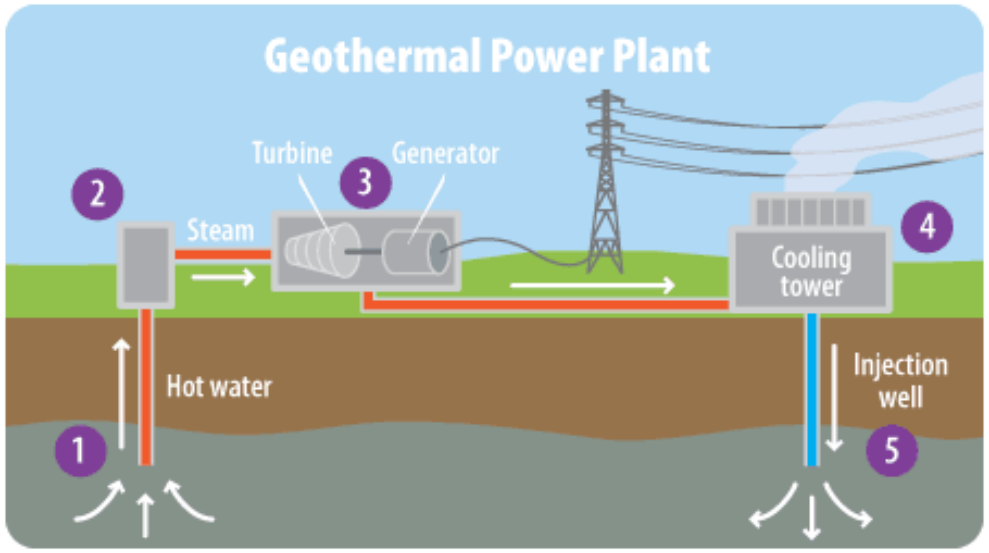
solantro®
SEMICONDUCTOR CORP.

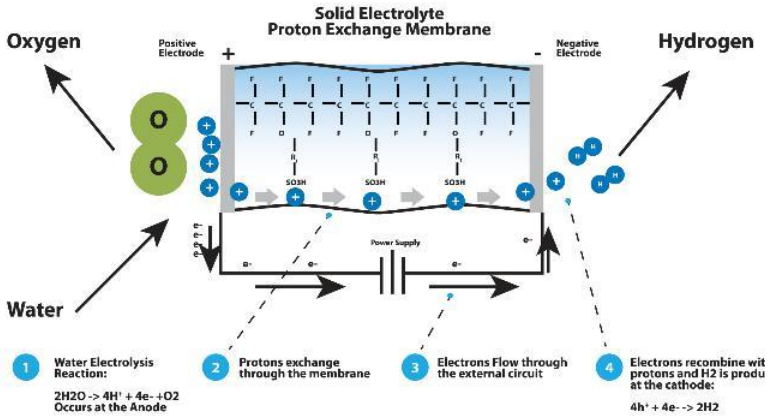
Renewable Energy Growth with New Power Semiconductor Devices and Integrated Circuits

Tanya Kirilova Gachovska

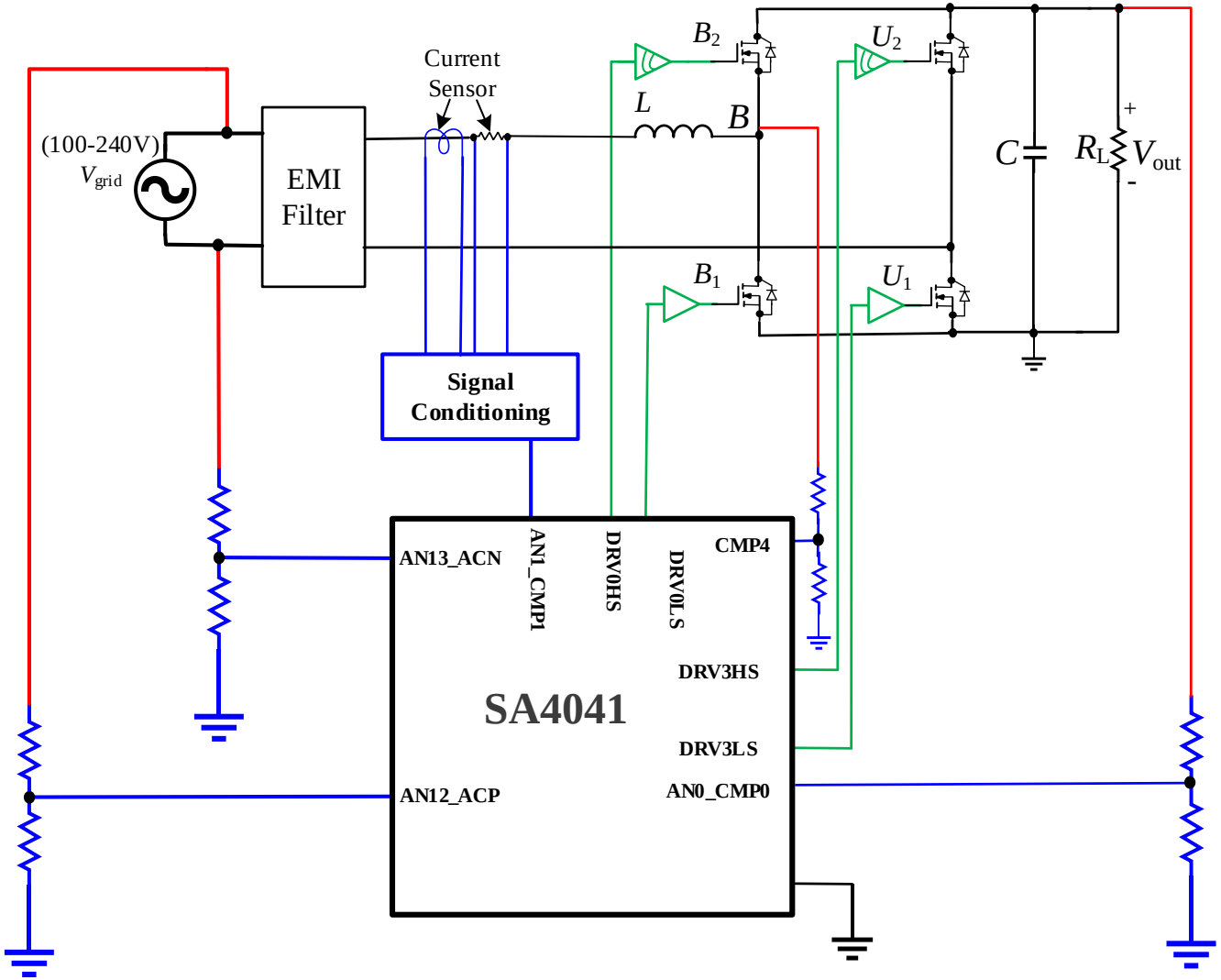
November 8, 2019

Renewable energy





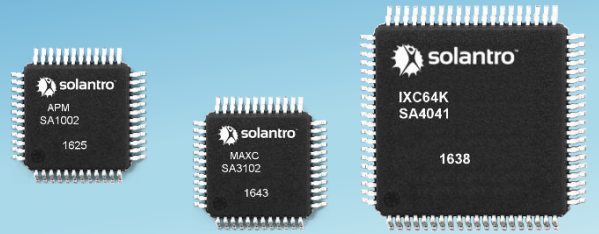
A Power Electronics Application



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

Power semiconductors devices

- Power semiconductors devices
  - Silicon
    - Diodes
      - Schottky
      - Epitaxial (PIN)
      - Double diffusion (PIN)
    - Transistors
      - BJT
        - NPN
        - PNP
      - MOSFET
        - N-channel
          - Conventional
          - Super junction
          - CoolMOS
        - P-channel
      - IGBT
        - Conventional
        - NPT
        - PT
        - Trench
    - Thyristors
      - Fast thyristors
        - Symmetric
        - Asymmetric
        - Reverse
      - GTO
        - Symmetric
        - Asymmetric
        - Reverse
      - IGCT
        - Asymmetric
        - Reverse
      - MCT
        - P-type
        - N-type
      - MTO
  - Silicon Carbide
    - Diodes
      - Schottky
      - Epitaxial (PiN)
    - Transistors
      - NPN BJT
      - DMOSFET
      - JFET
      - IGBT
    - Thyristors
  - Gallium Nitride
    - Diodes
      - Schottky
      - Epitaxial (PiN)
    - Transistors
      - HEMT
      - MOSFET
      - JFET


solantro
APM
SA1002
1625
solantro
MAXC
SA3102
1643
solantro
IXC64K
SA4041
1638

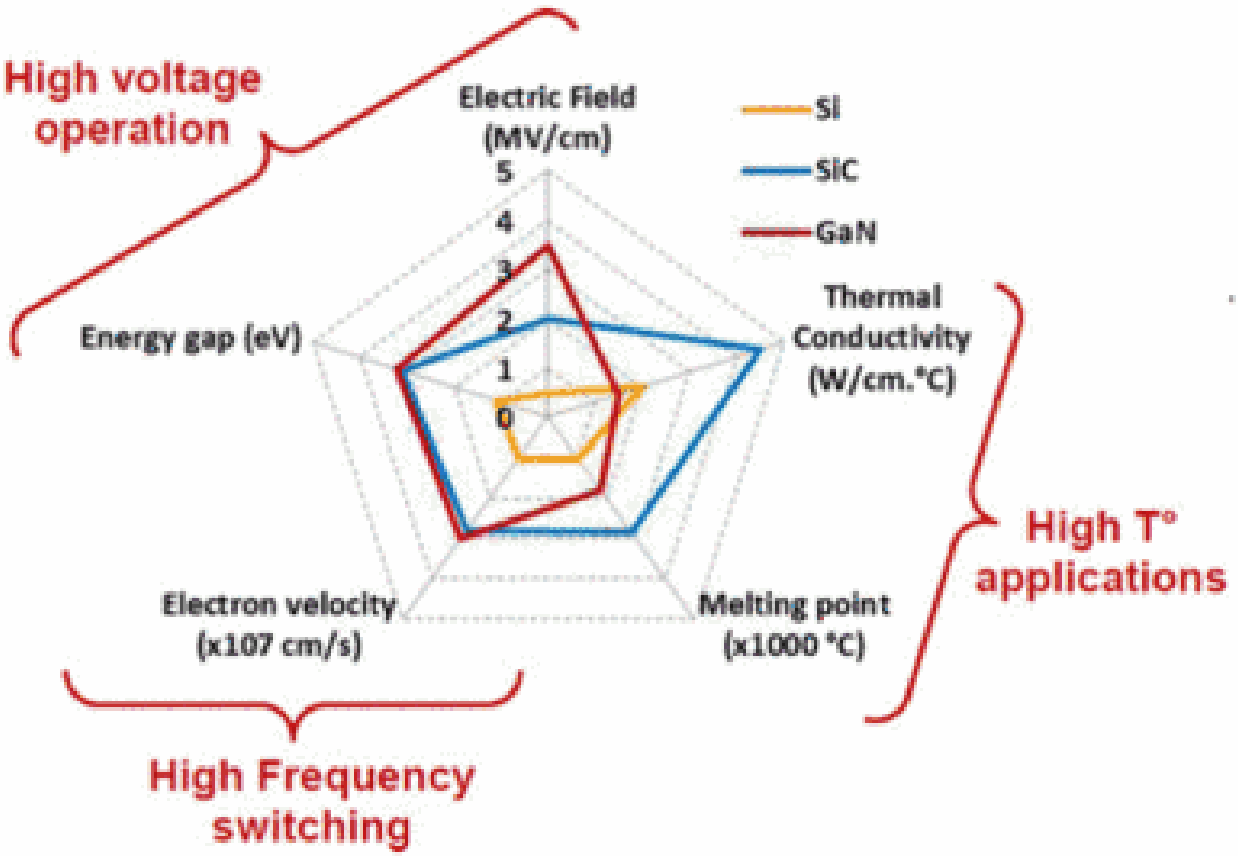
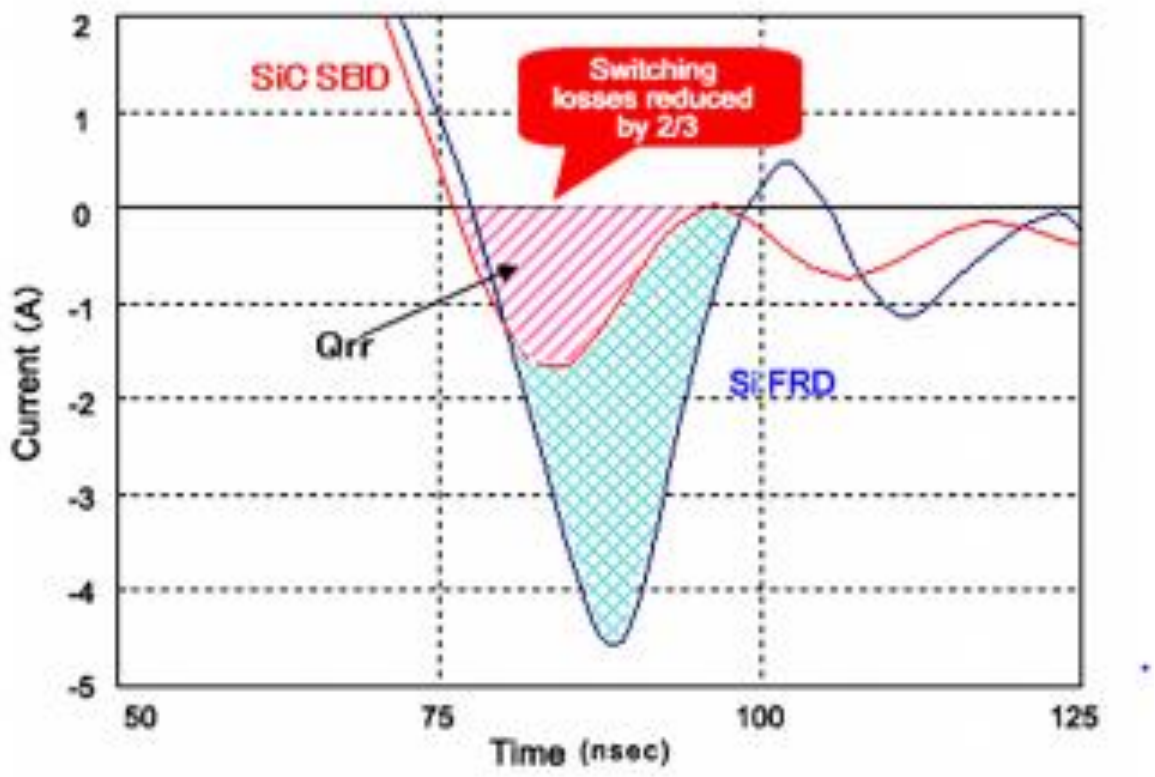
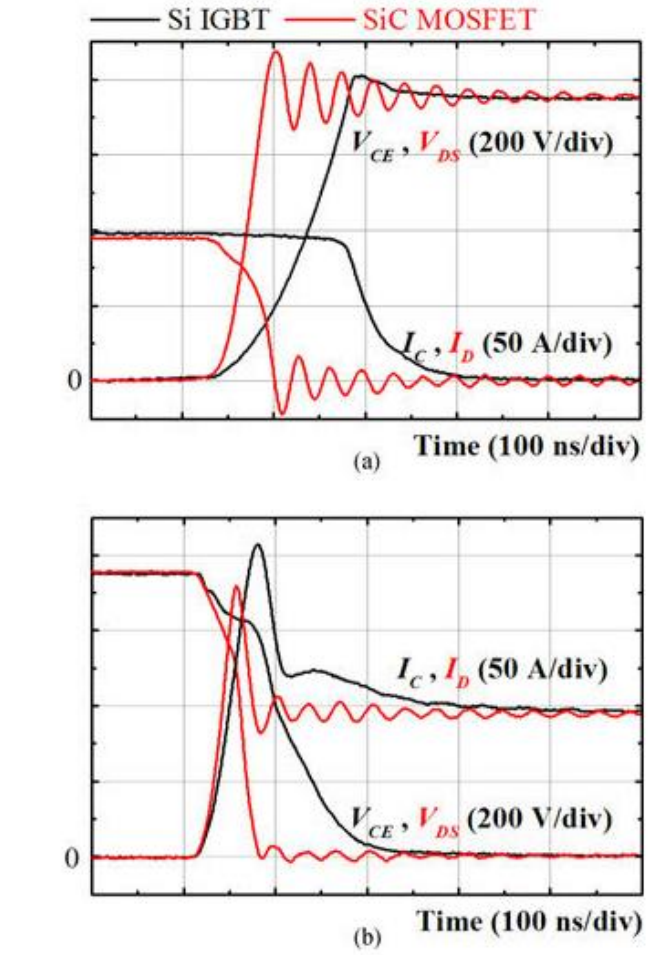

High voltage operation
Electric Field (MV/cm)
5
4
3
2
1
0
Si
SiC
GaN
Energy gap (eV)
Thermal Conductivity (W/cm.°C)
Electron velocity (x107 cm/s)
Melting point (x1000 °C)
High T° applications
High Frequency switching

Table 1. Physical properties for various semiconductors.

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

$$R_{SP-ON} = \frac{1.716 \times 10^{-6} \varepsilon_r BV^{2.5} E_G^{-3}}{\mu_n} \qquad R_{SP-ON} = \frac{3.351 \times 10^{-3} BV^2 E_G^{-6}}{\varepsilon_r \mu_n} \qquad R_{SP-ON} = \frac{8.725 \times 10^{-3} BV^2 E_G^{-7.5}}{\varepsilon_r \mu_n}$$


SiC SBD
Switching losses reduced by 2/3
Qrr
Si FRD
Current (A)
Time (nsec)
2
1
0
-1
-2
-3
-4
-5
50
75
100
125



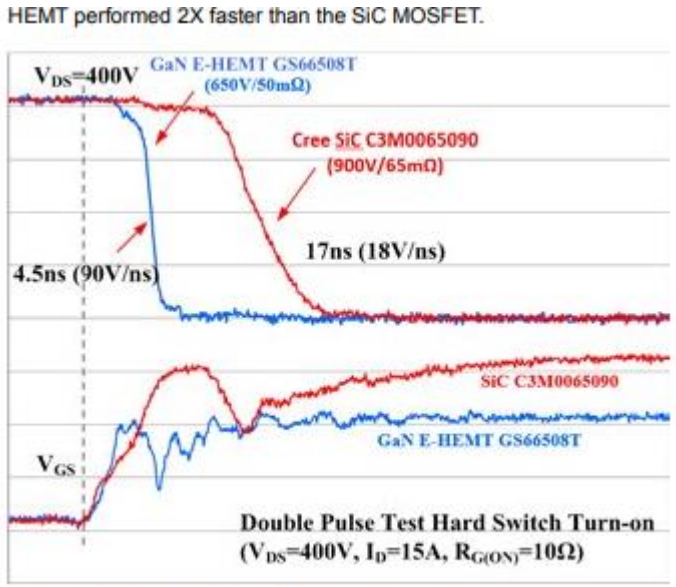


Figure 5: Double Pulse Test Hard Switch Turn-on

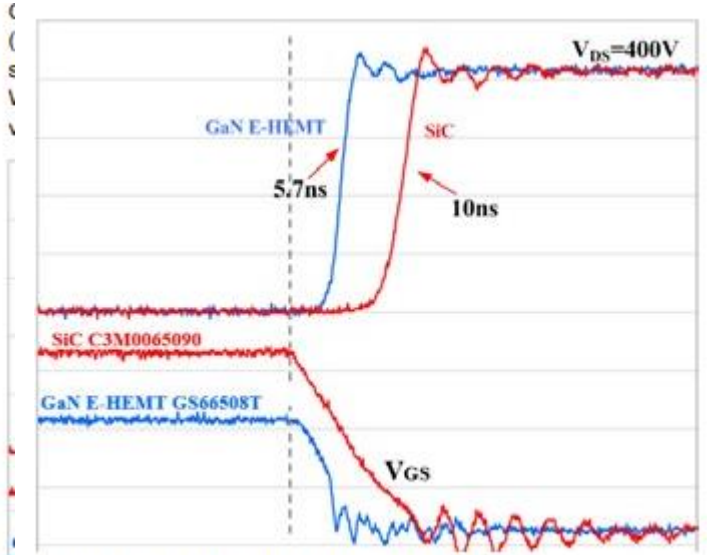
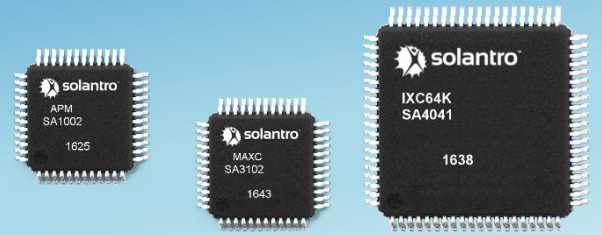


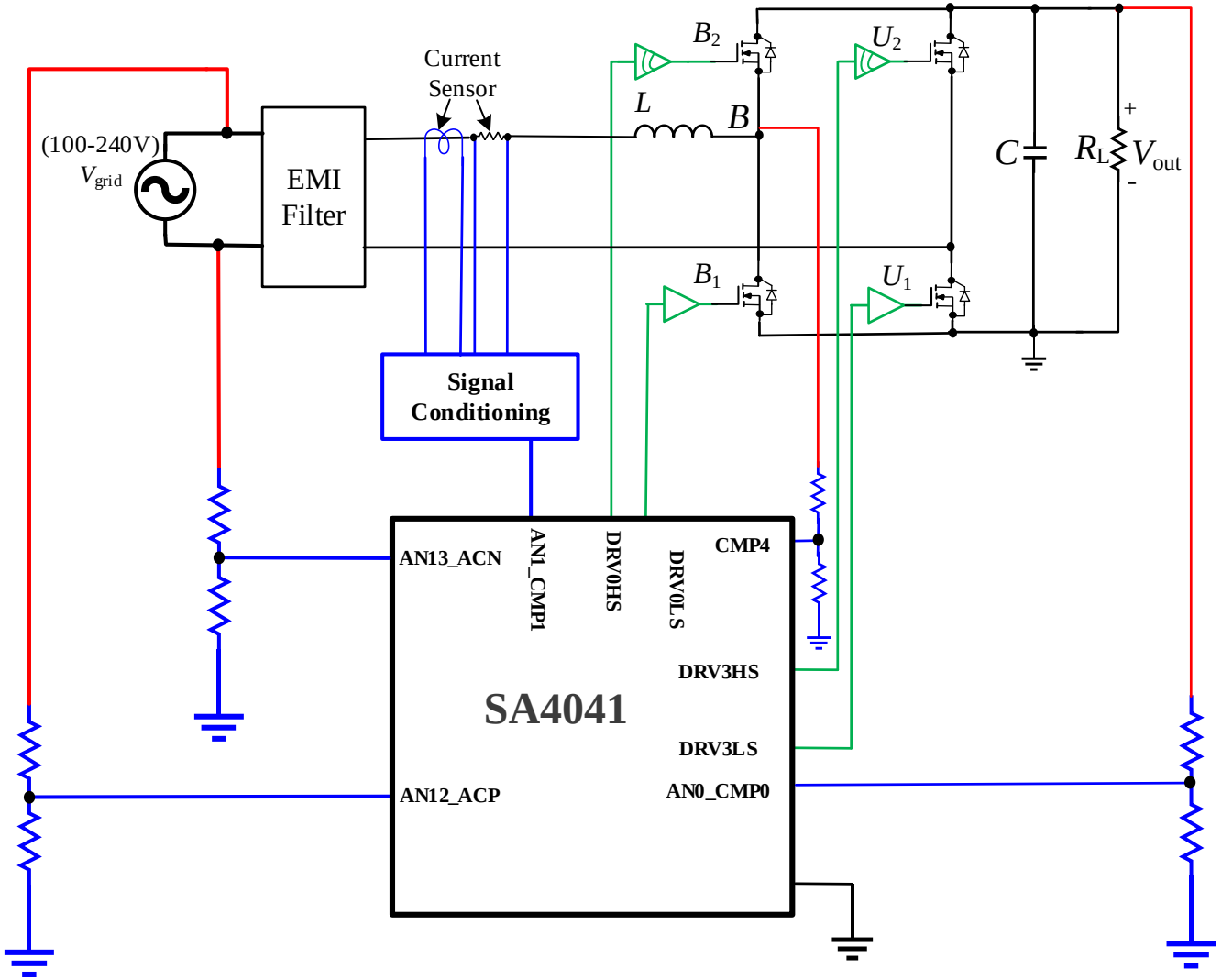
Figure 6: Double Pulse Test Hard Switch Turn-off

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

A Power Electronics Application





1) Power switches;
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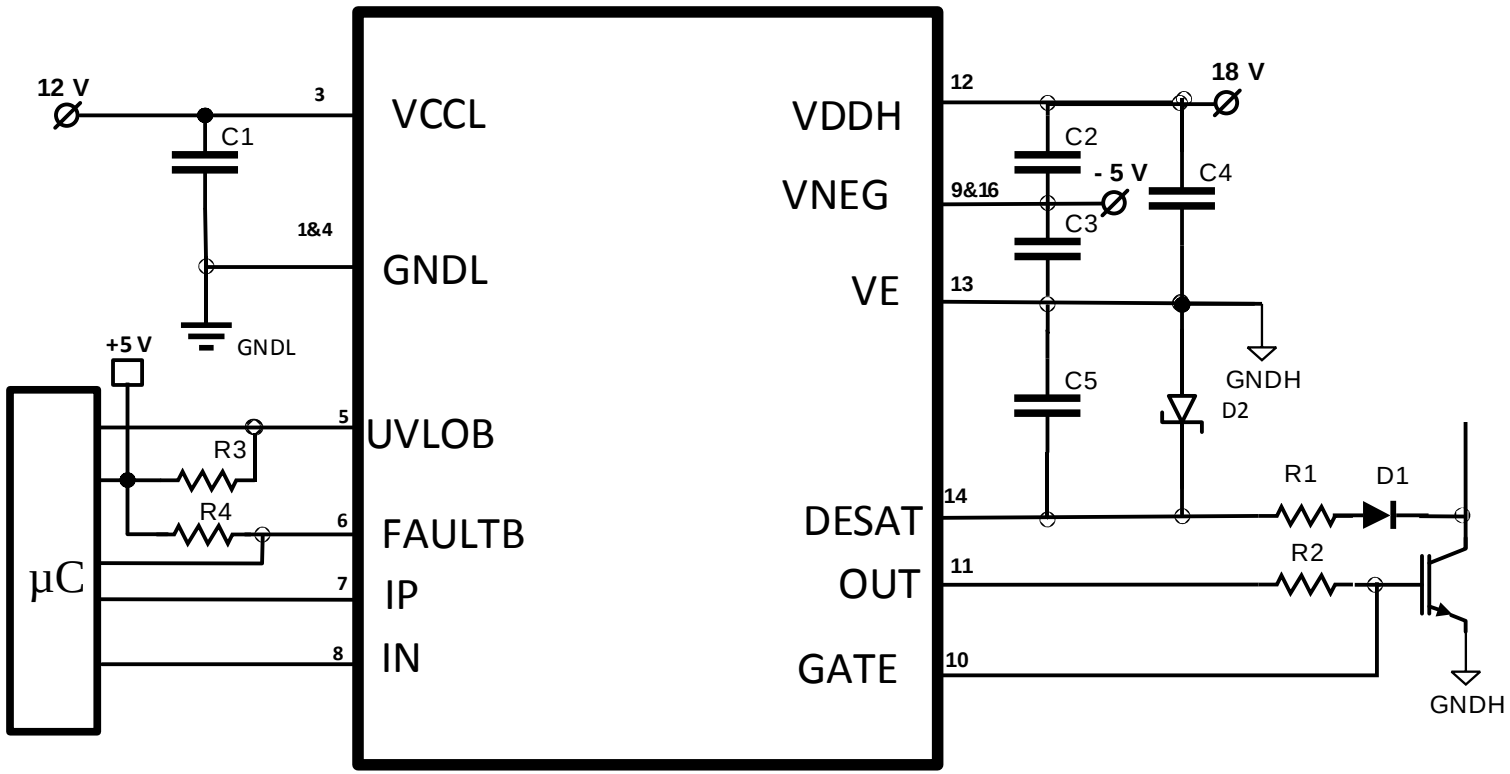
4) Microcontroller

Gate drivers

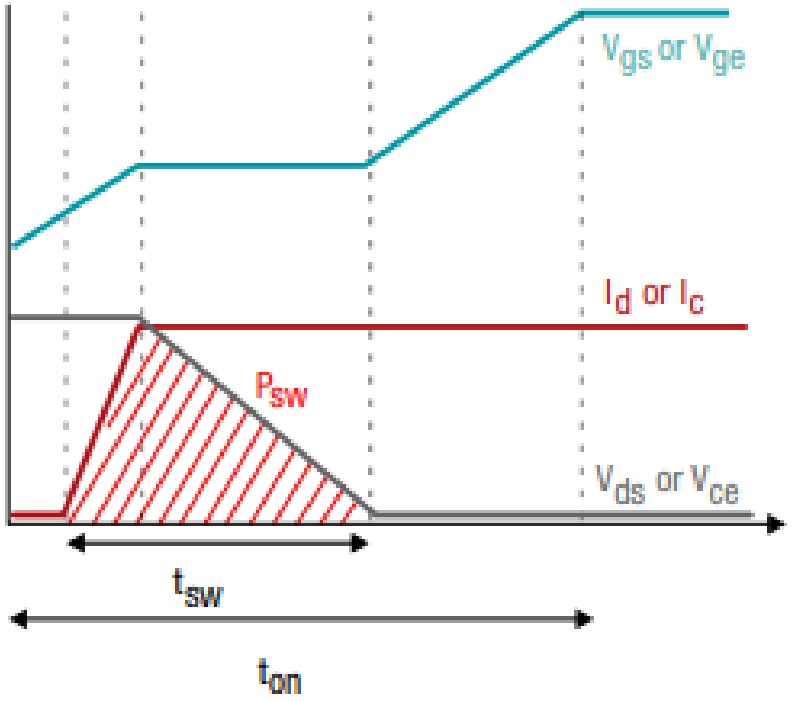


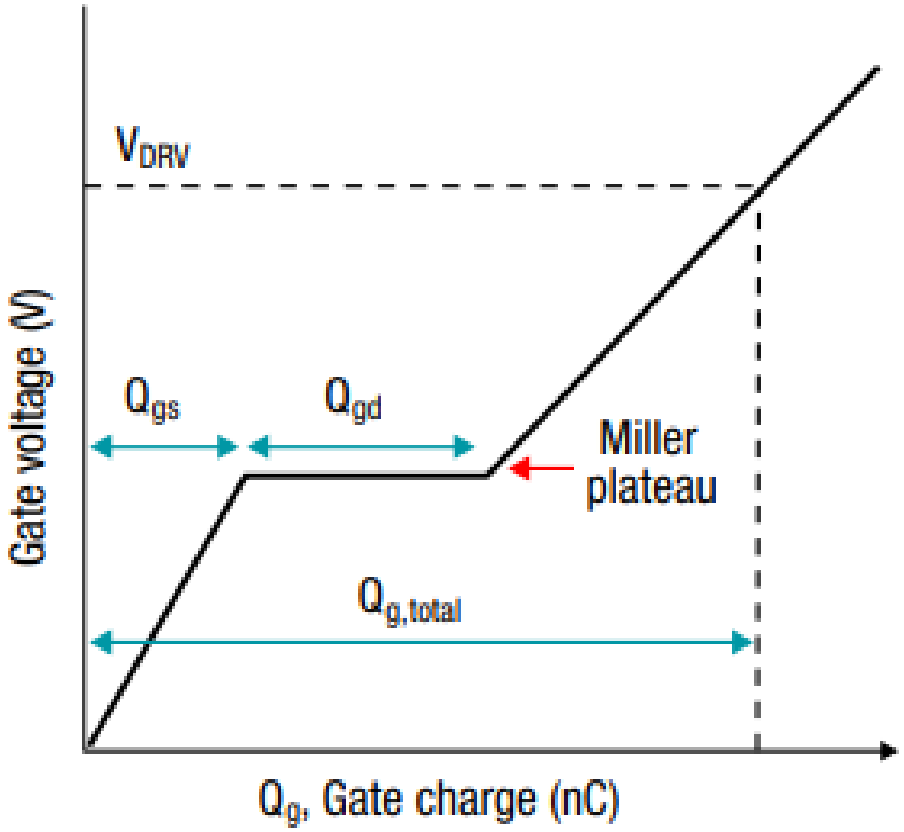
Typical application configuration of Solantro SA6880-S gate driver

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)

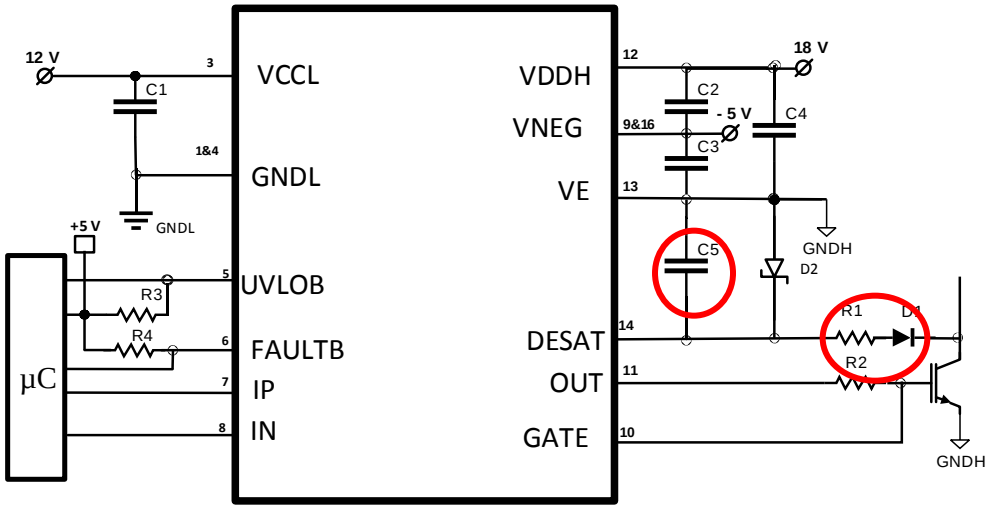
Turn ON switching of MOSFETs

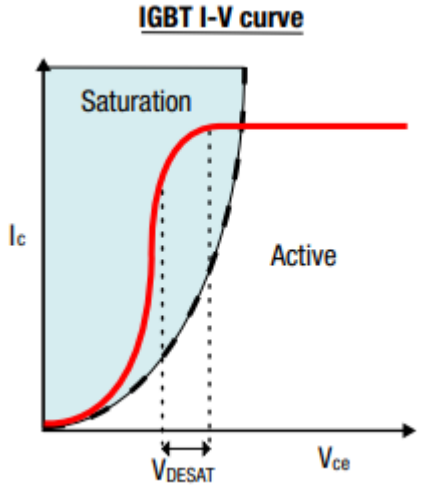


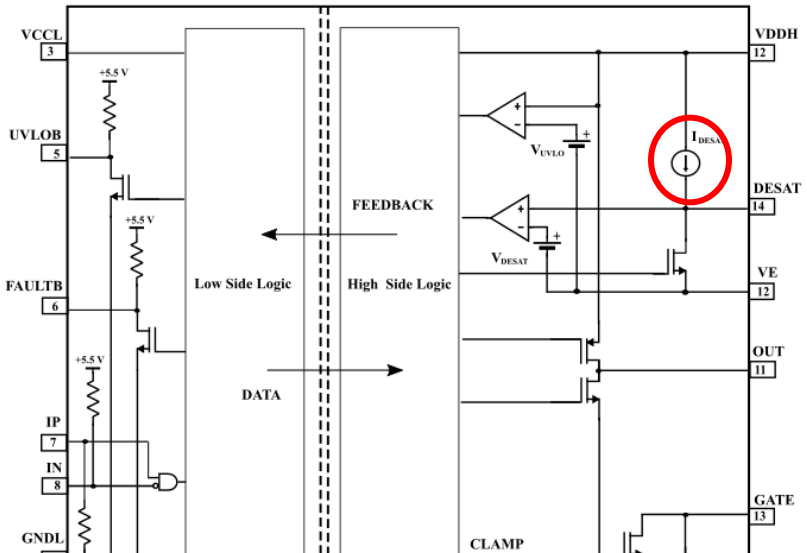


High **peak output driver current** → Fast switching → Low losses → High switching frequency

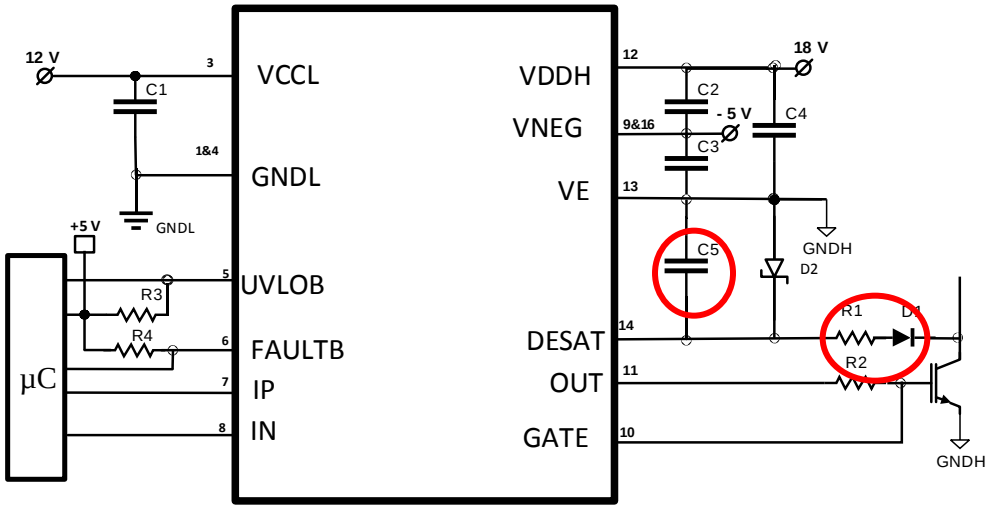
DESAT with soft shutdown

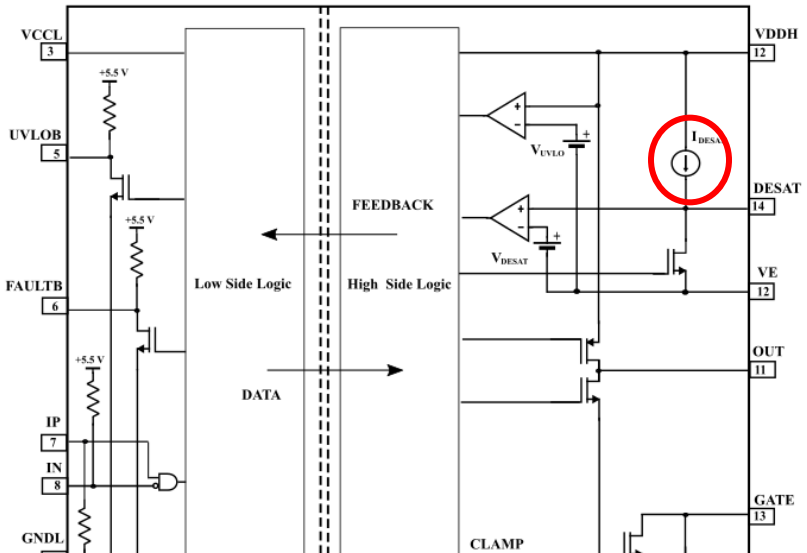




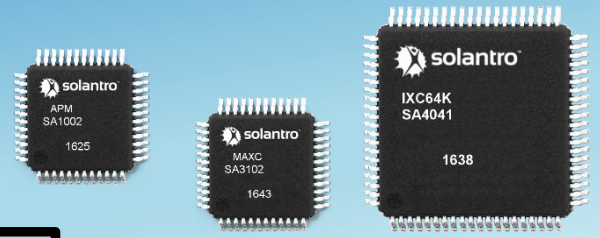


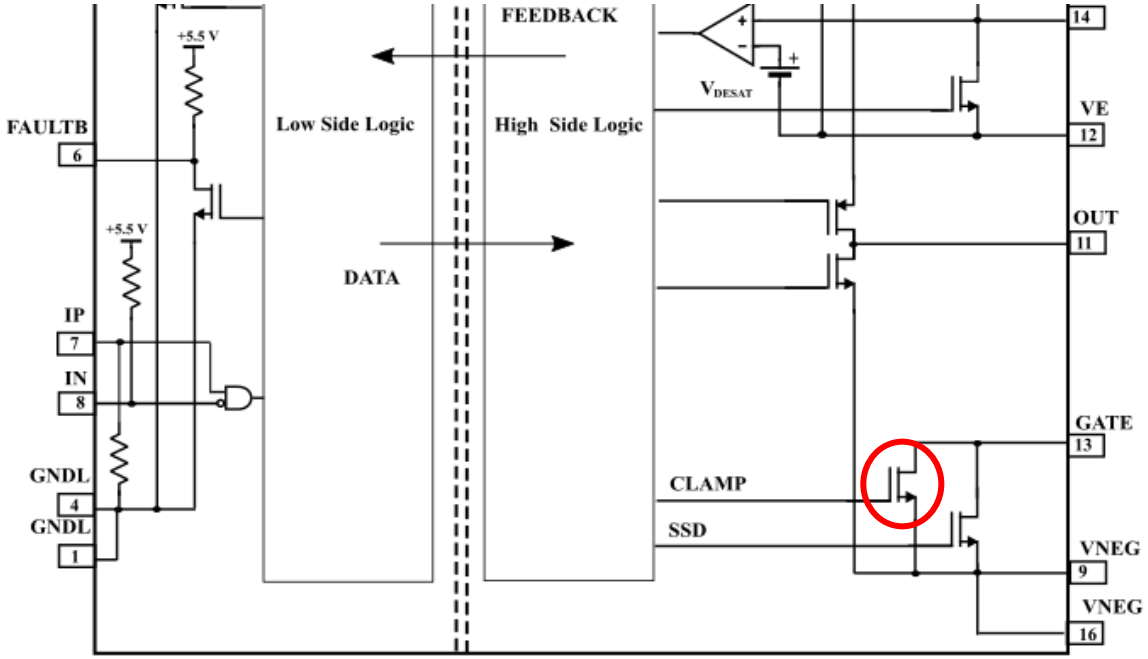
DESAT with soft shutdown

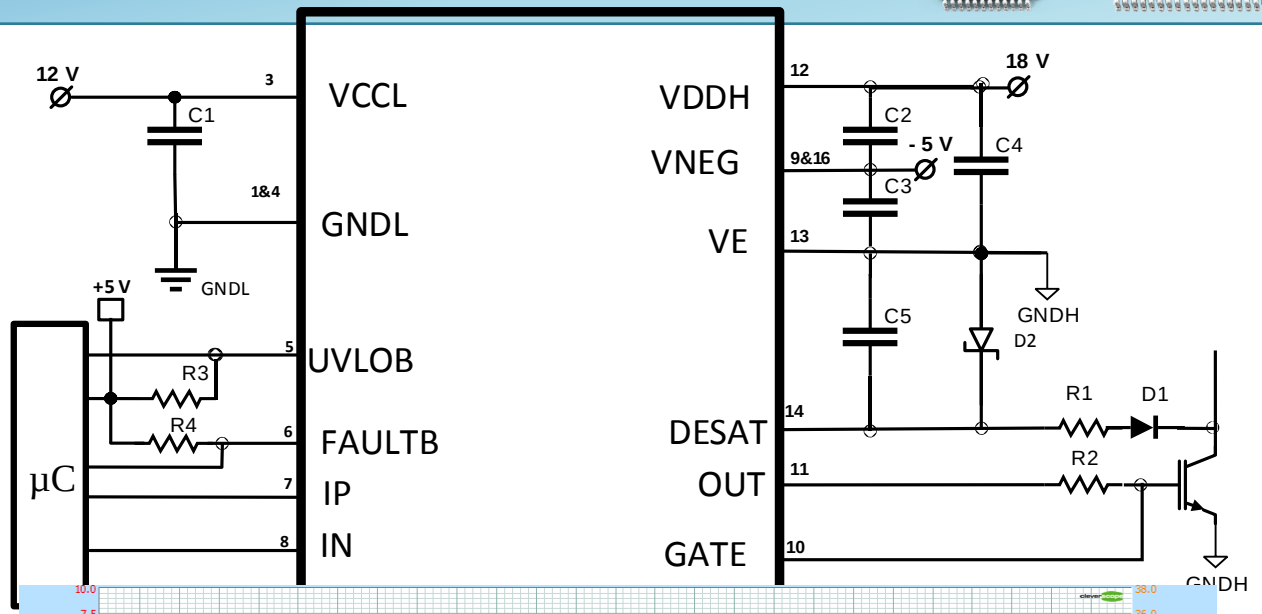


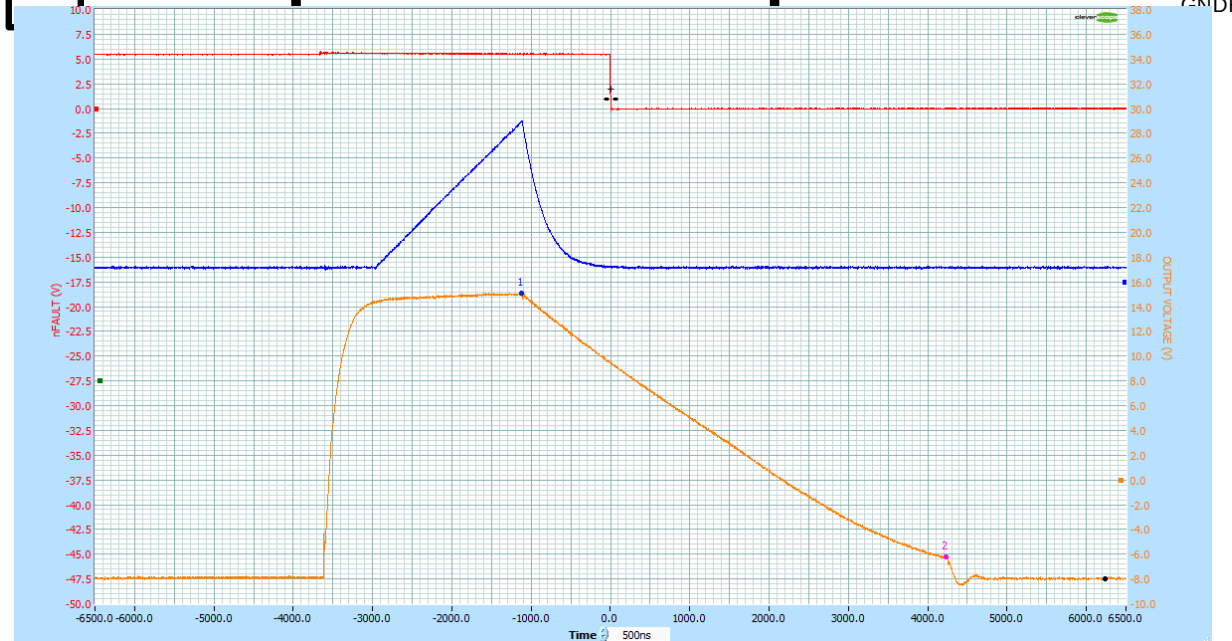


Miller Clamp

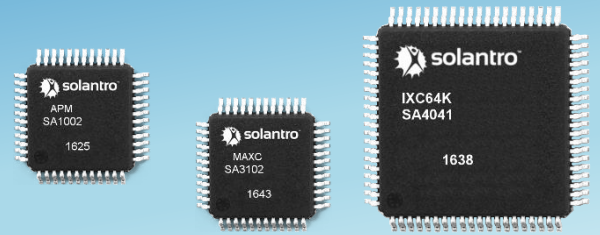


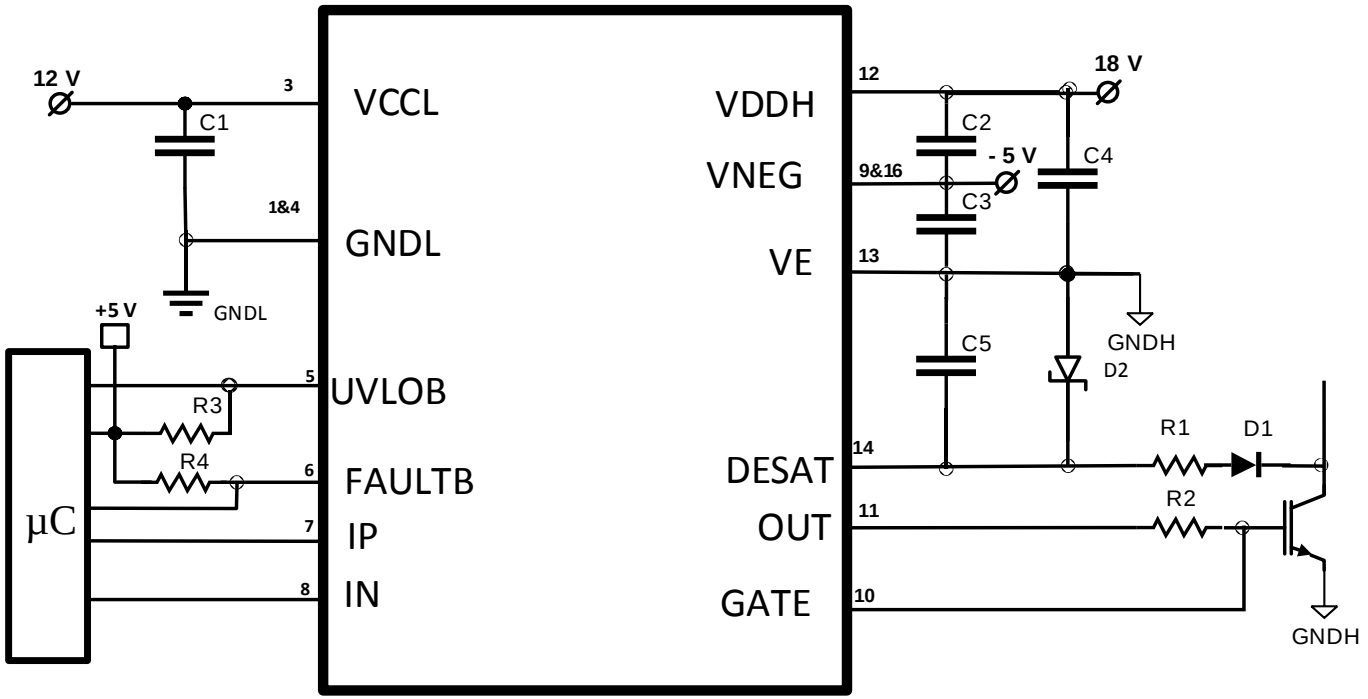






UVLO

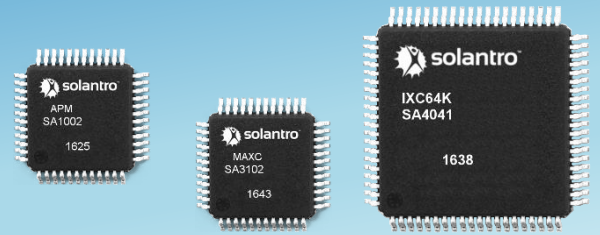


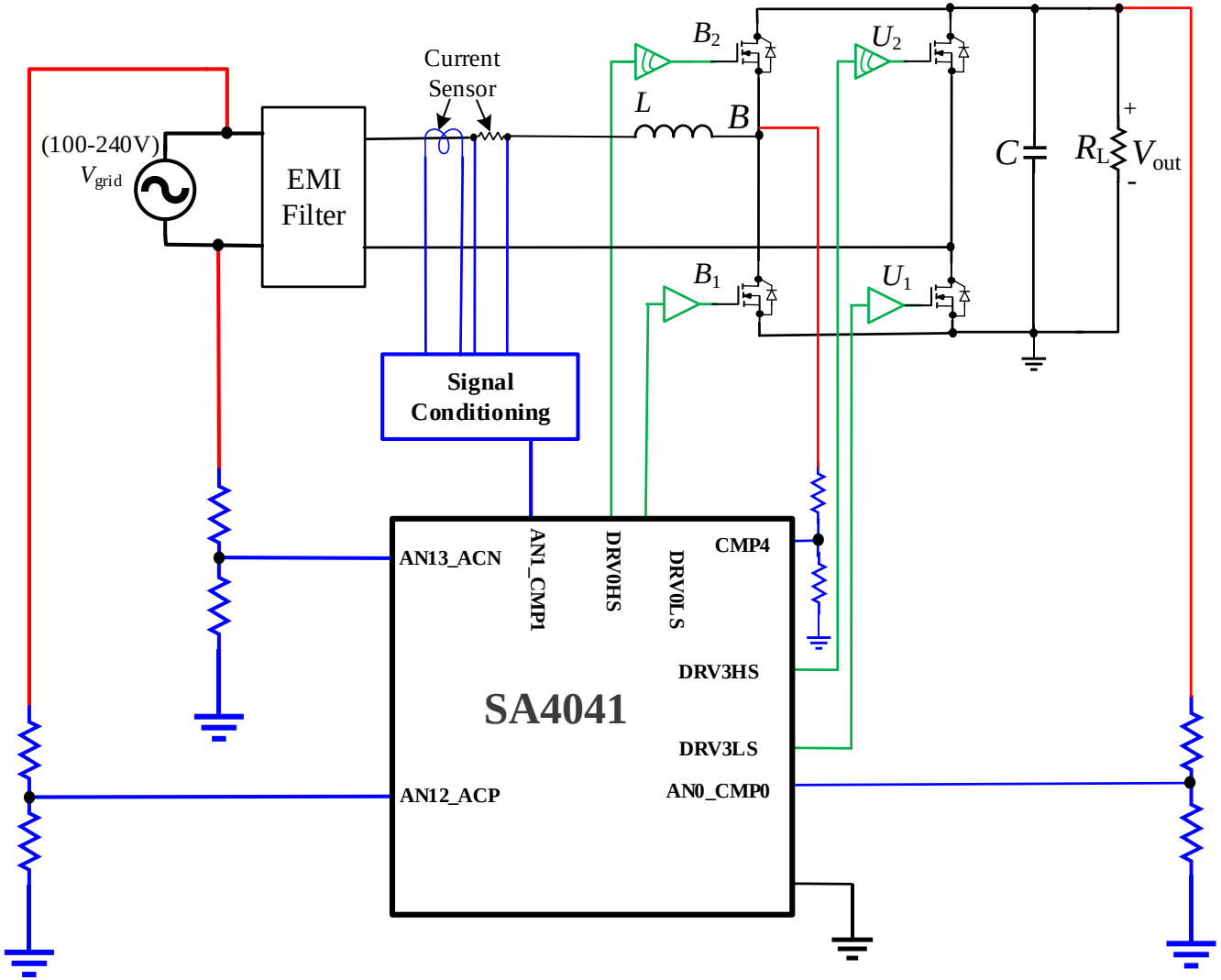


High **gate source voltage** → Fast switching → Low losses → High switching frequency

Low **gate source voltage** → Slow switching → High losses → High temperature → Destroy switch

A Power Electronics Application





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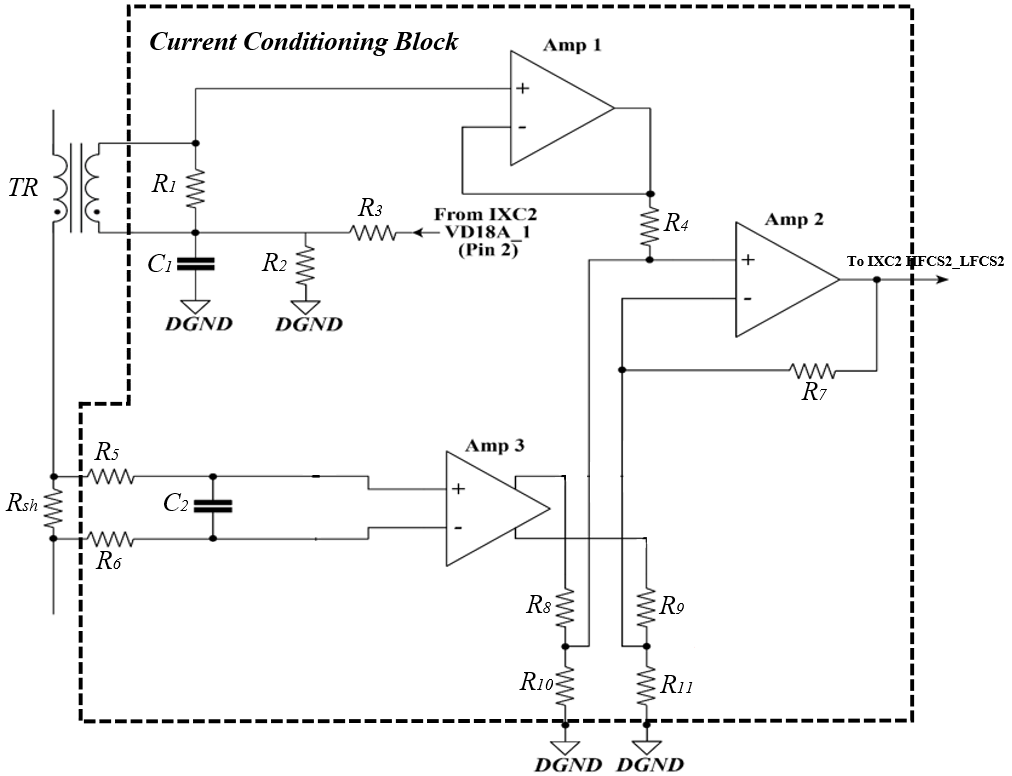
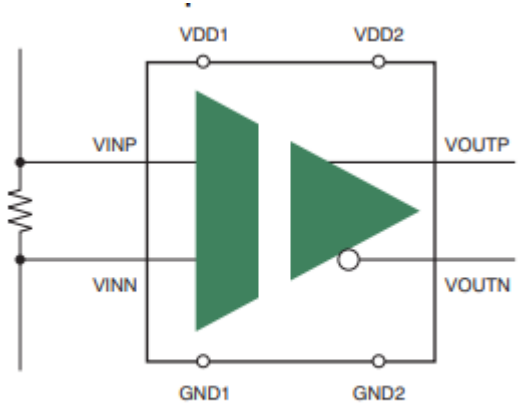
An example of current sense circuit



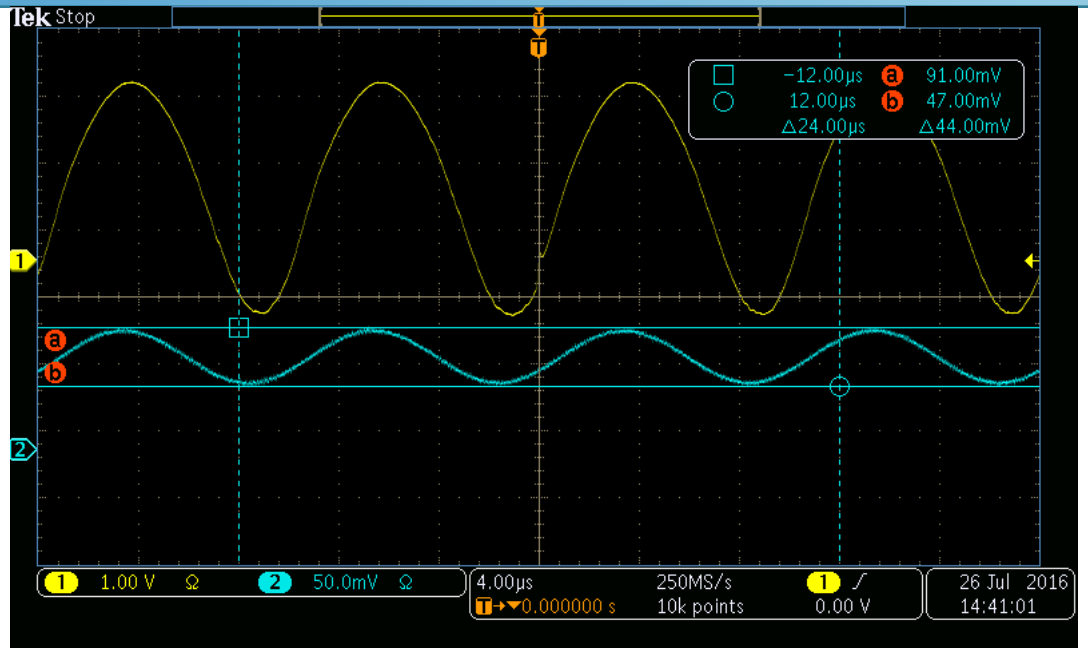
Some Features of Solantro CSA

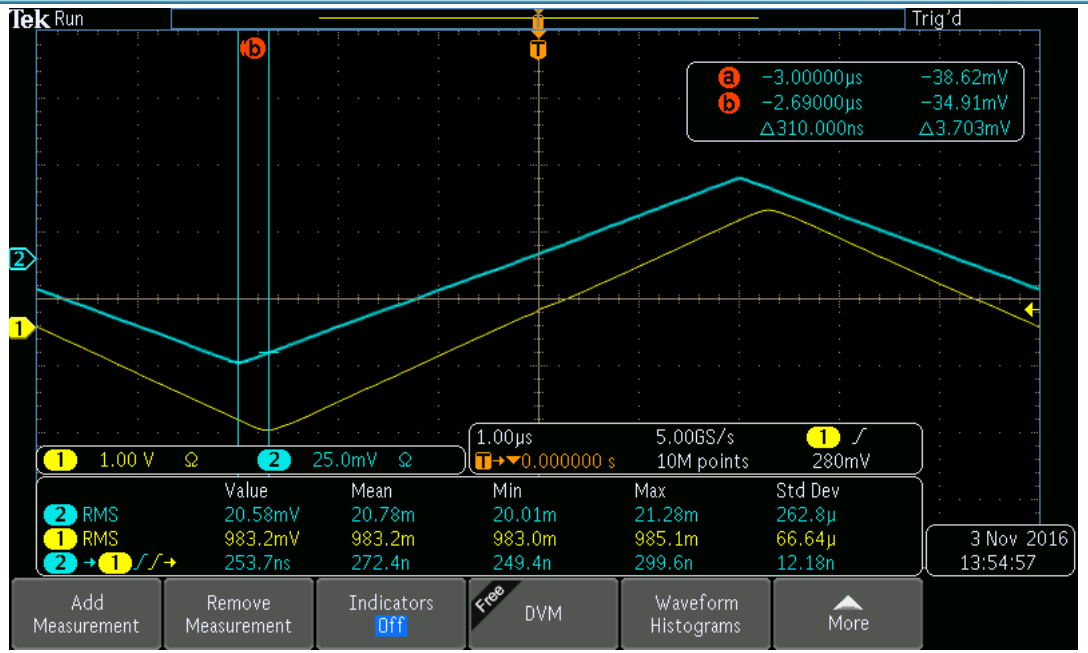
- ±250 mV input voltage range optimized for shunt resistors
- Very low nonlinearity: 0.075% maximum
- Low input offset voltage: 200 µV typical
- Low noise: 3.1 µVrms typical
- Delay: 350 ns/700 ns
- Input bandwidth: 500 kHz typical
- Nominal gain: 8 (gain error ±0.5%)
- 100 V/ns transient dv/dt immunity
- 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

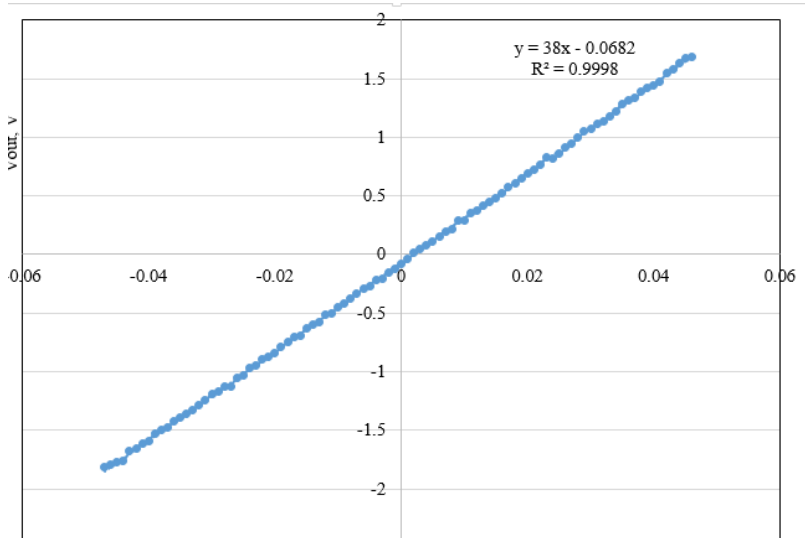
- Operating temperature range -40℃ to 125℃



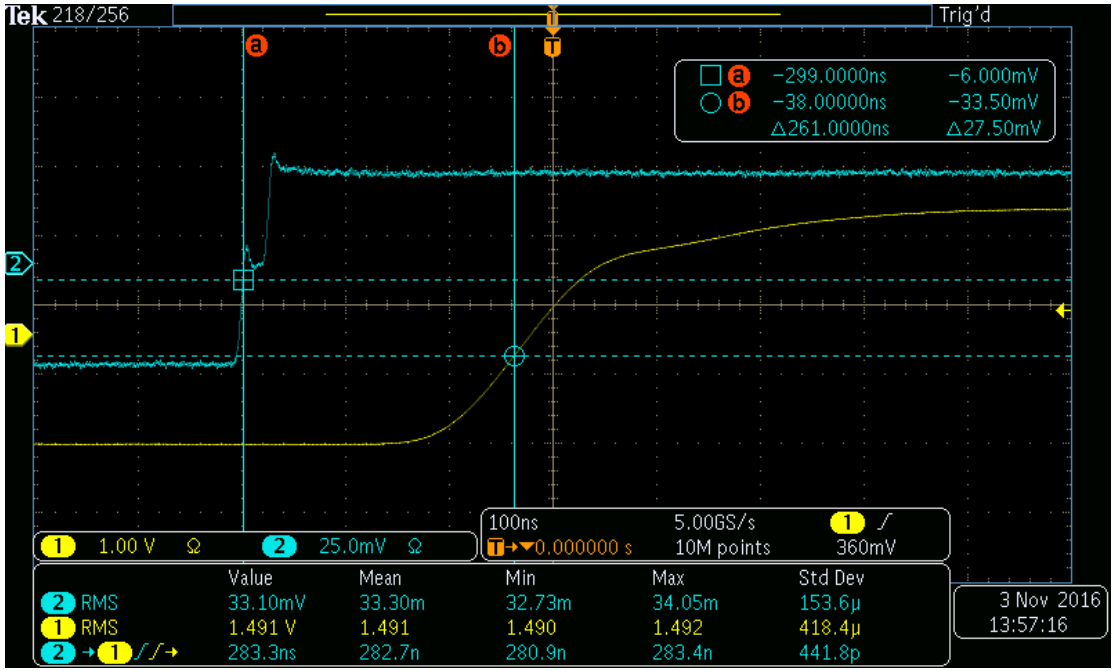
Input output



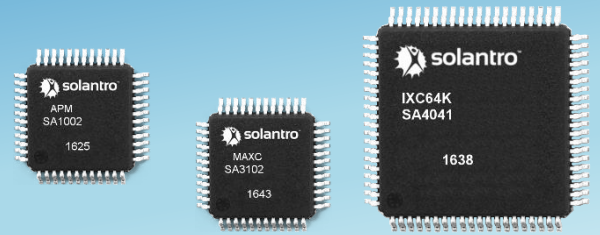


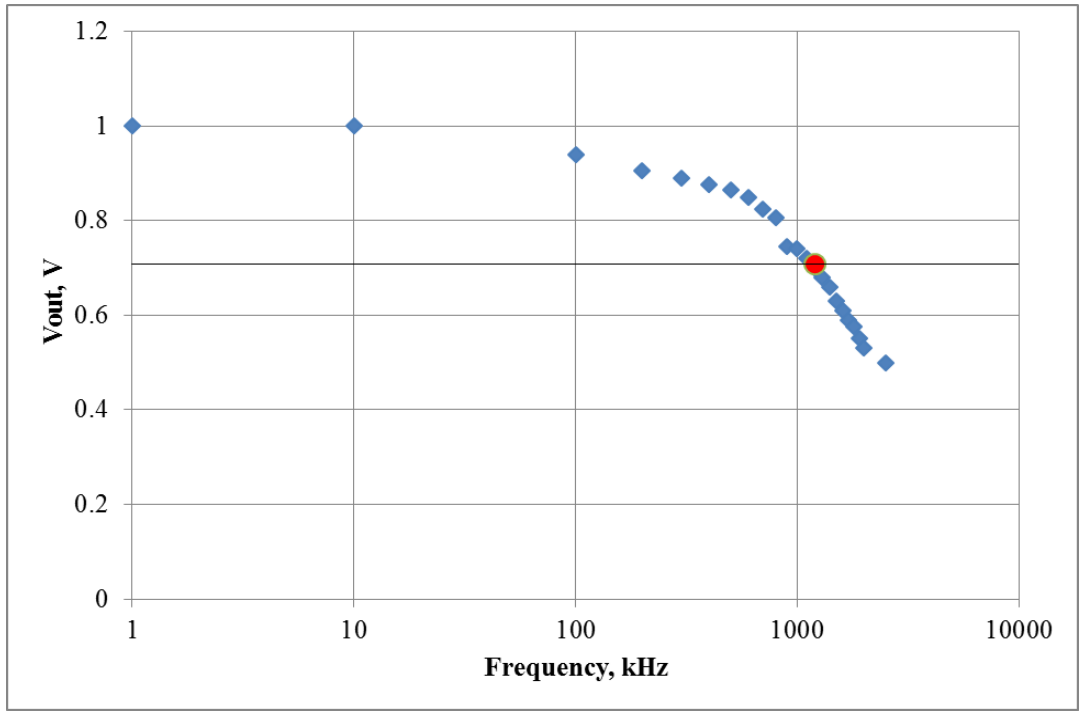


Propagation Delay



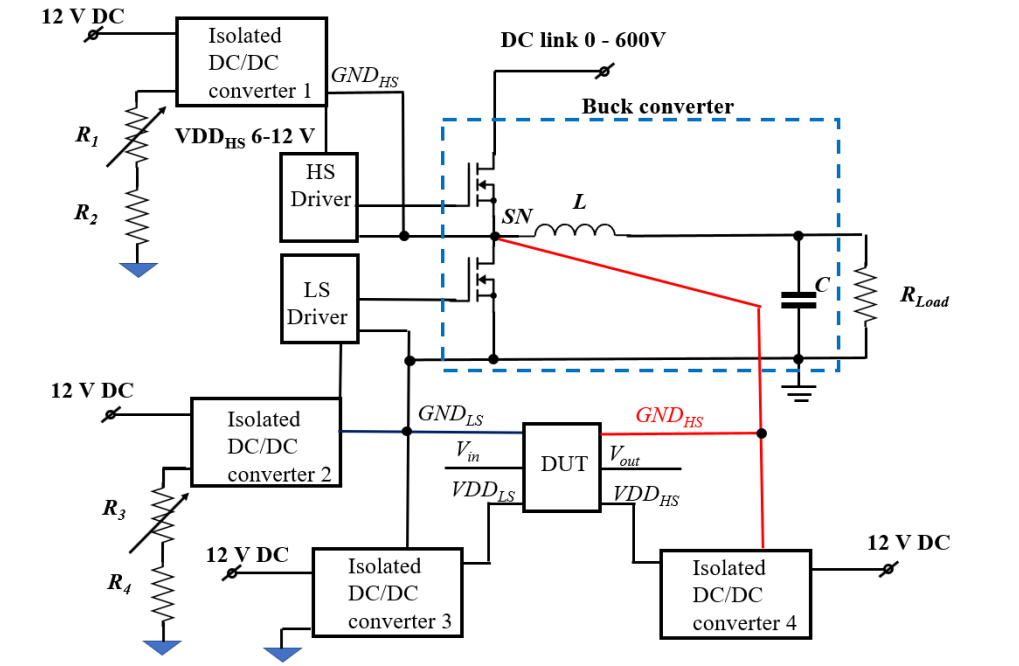
Bandwidth



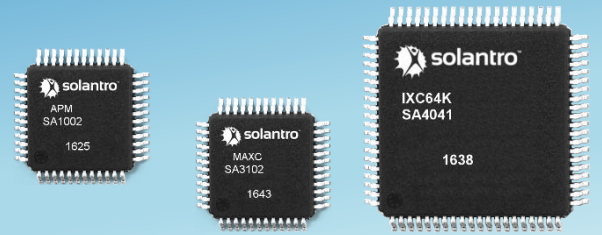


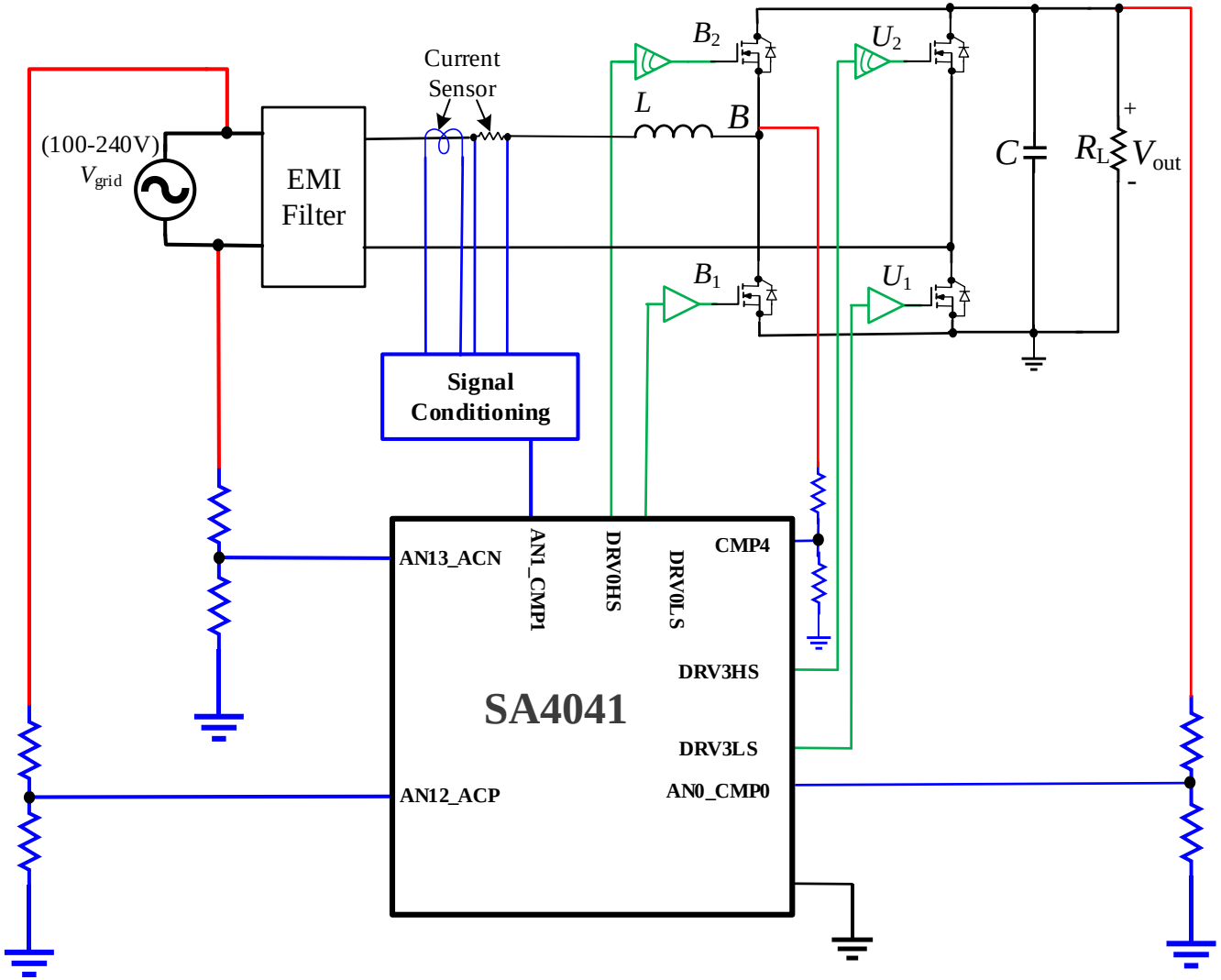
FICS amplifier normalized output voltage in function of frequency

Circuit for testing Common mode immunity



A Power Electronics Application





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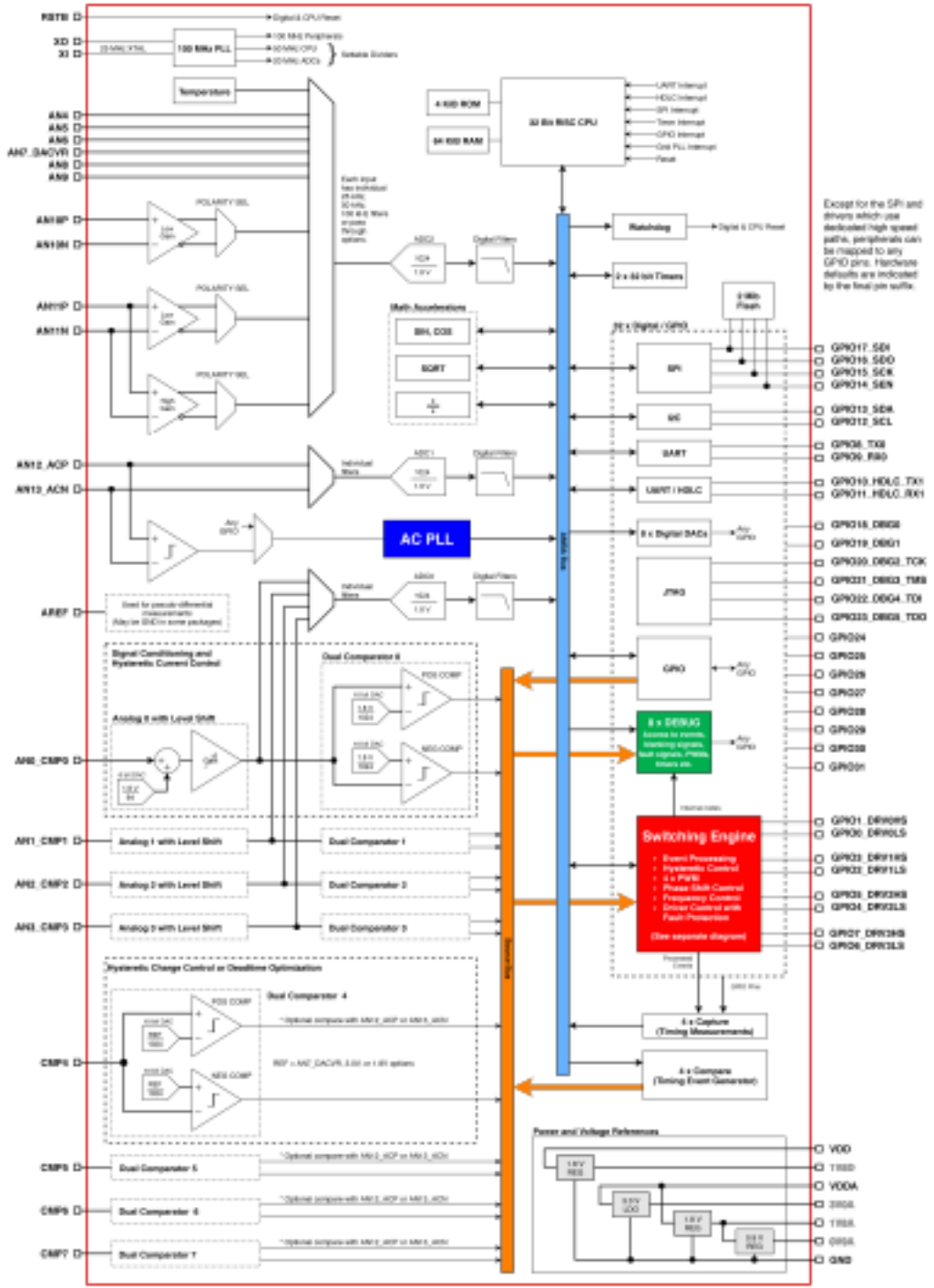
Functional block diagram

Rich power control-centric analog Peripherals:

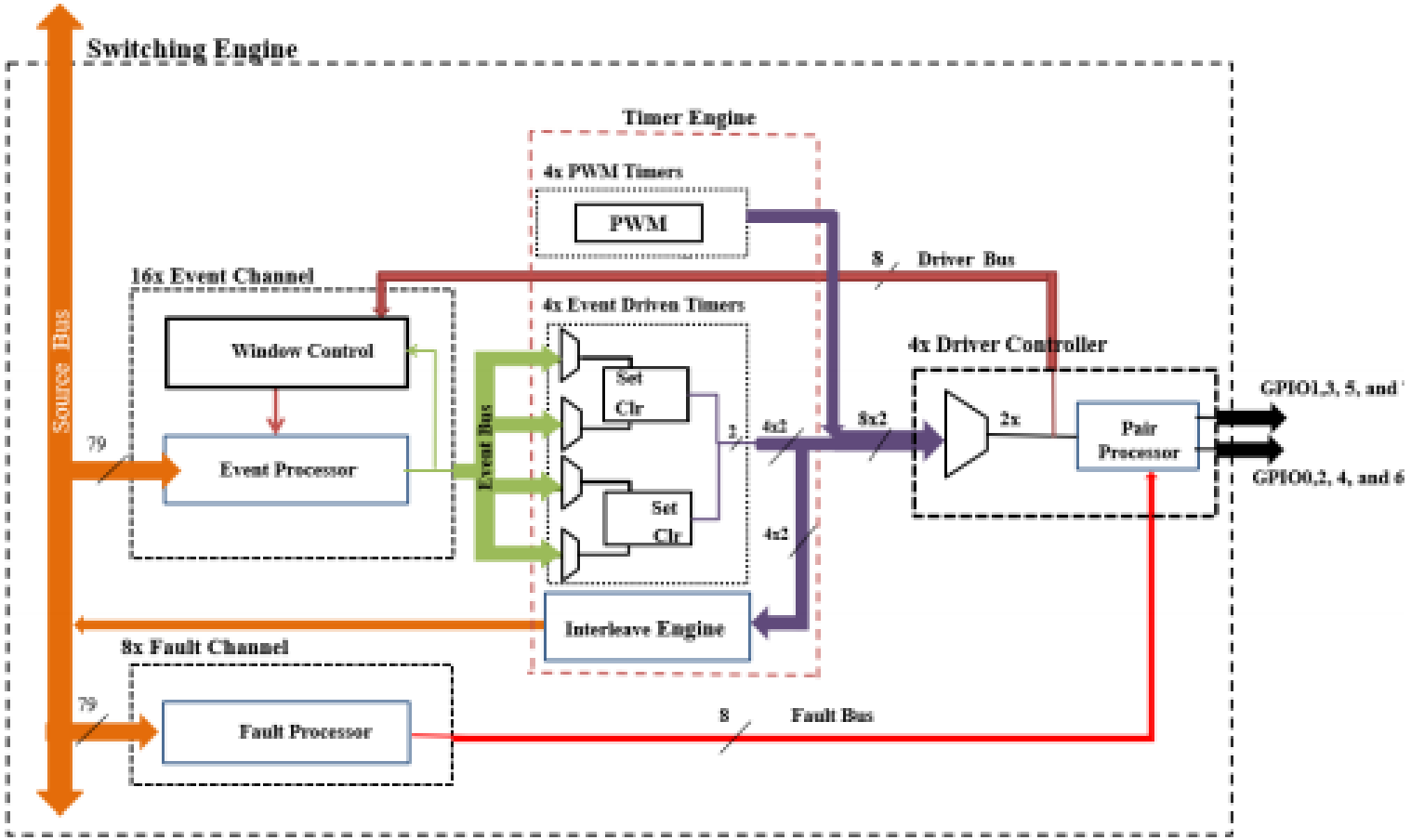
- Sixteen-channel, 10-bit, 1.4 MS/s ADC
- 2 four-channel, 10-bit, 1.4 MS/s ADC
- 17 10 ns fast comparators
- 24 10-bit analog DACs for internal comparator threshold settings
- Two differential high-speed current sensing amplifier interfaces
- Programmable anti-alias low-pass filters
- Temperature sensing

Digital Power Engine and Peripherals:

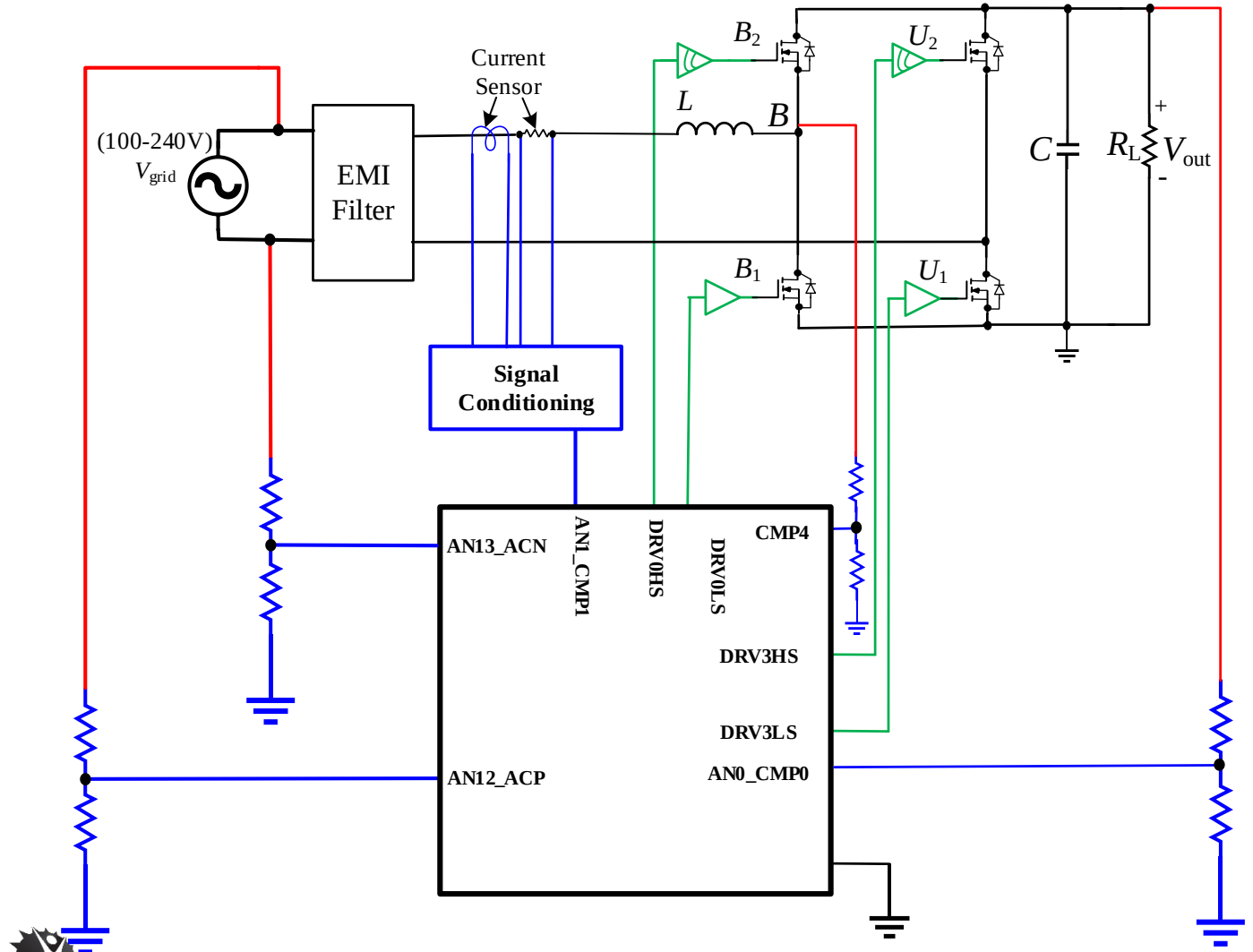
- 32-bit RISC CPU with 64 KiB RAM
- 256 KiB internal SPI flash memory
- Switching engine for up to 8 drivers with gate control for cross-conduction protection
- Four event-driven timing engines with sixteen event processing channels for hysteresis control.
- Four PWM timers (10ns resolution, 625ps fractional)
- 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^{o} C.

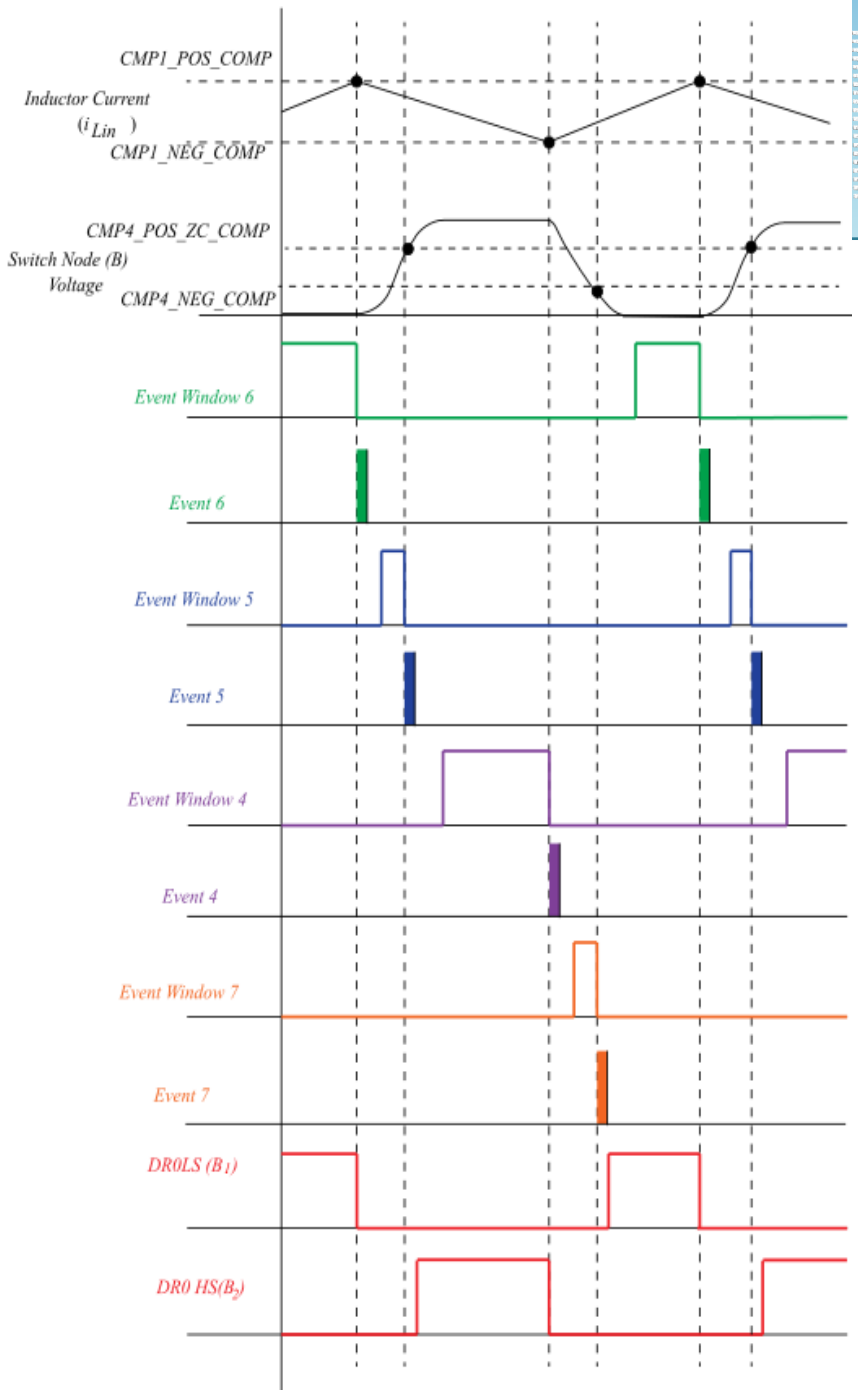


Switching Engine



Hysteretic control





Thank you