ISO6.4: The Past, Present, and Future of Current Sensing

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About the author

John Stevens is currently Director of Business Development at Navitas Semiconductor and is based out of Dallas, TX, USA. He has held various power electronics IC product definition, development, and marketing leadership roles at Texas Instruments over the previous 12 years. He's supported customers in AC/DC mobile and consumer electronics, telecommunications power, as well as Industrial and Automotive bias supplies. John holds a Bachelor of Science degree in Electrical Engineering from Clarkson University, Potsdam, NY, USA.

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The task of sensing current

Existing methods of current sensing and their benefits and challenges:

- Shunt resistors
- Current sense transformers
- Hall-effect
- AMR

New proposed method- Integrated “GaNSense”

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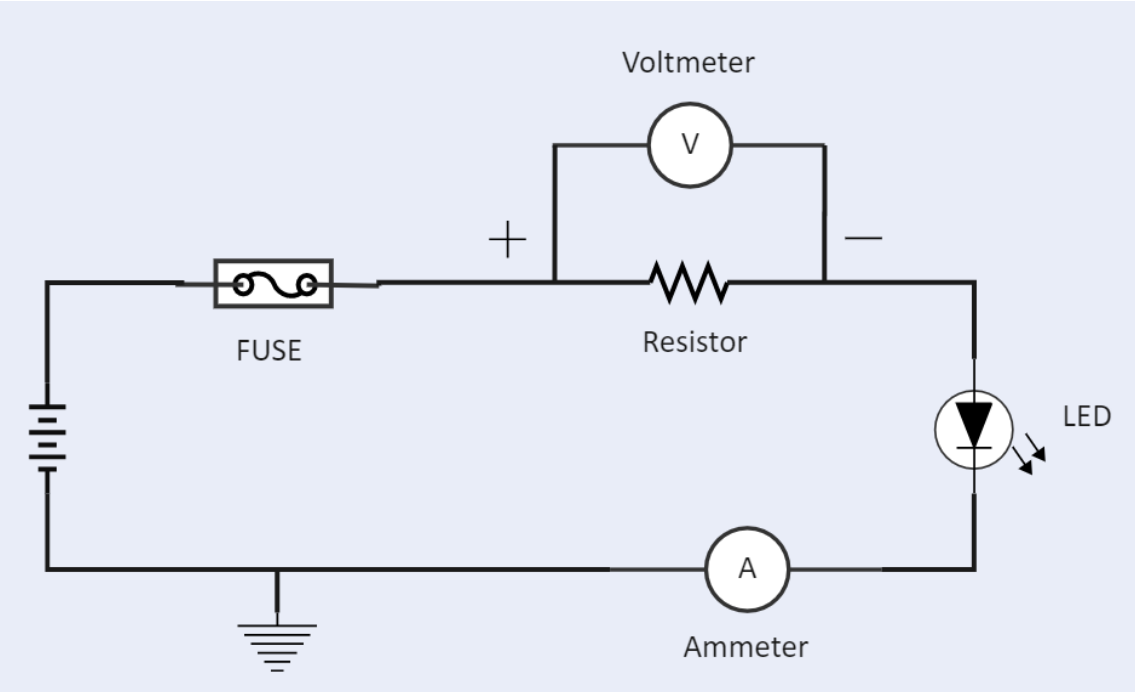
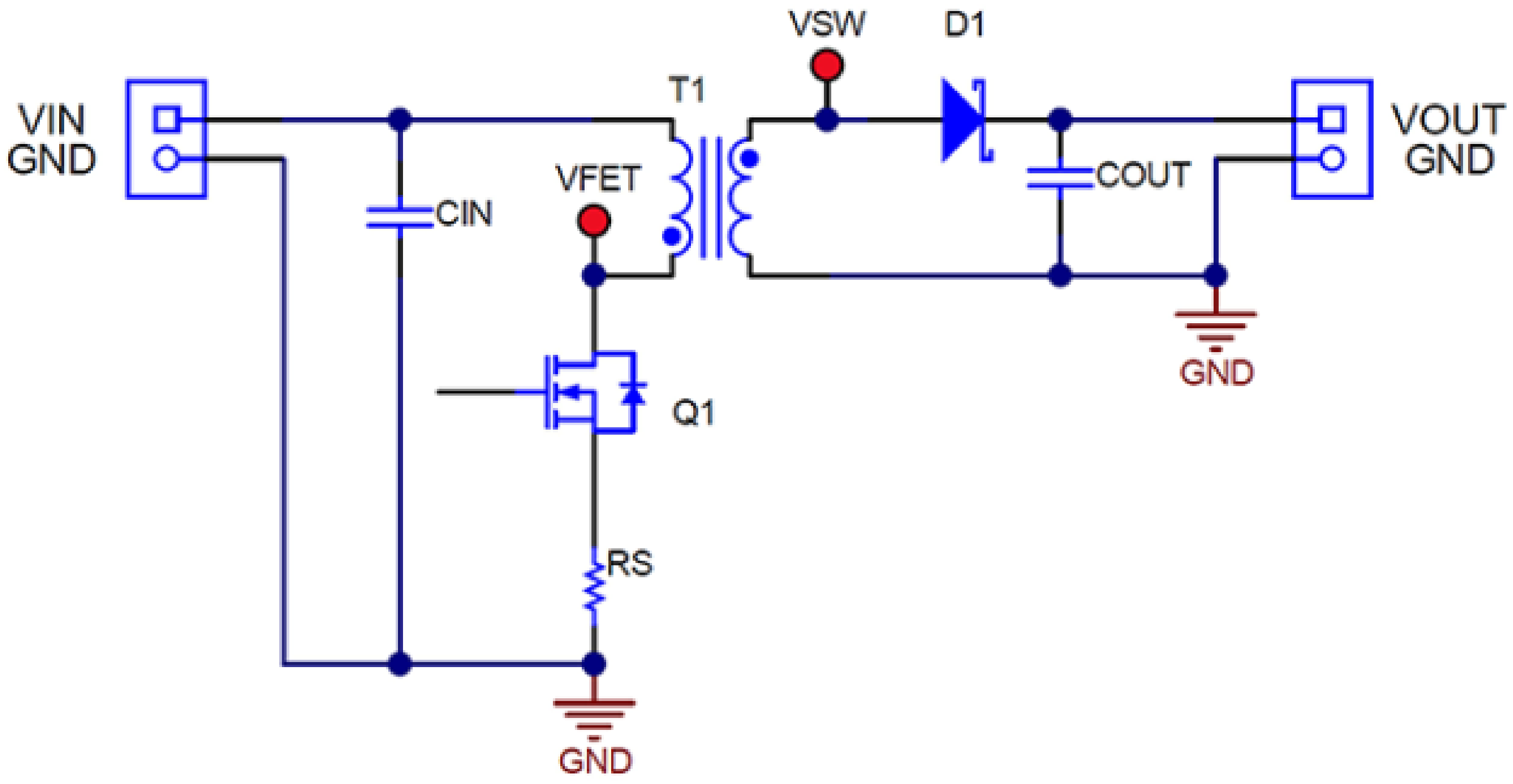
Impacts of optimized sensing and where it could go next

The task of sensing voltage and current



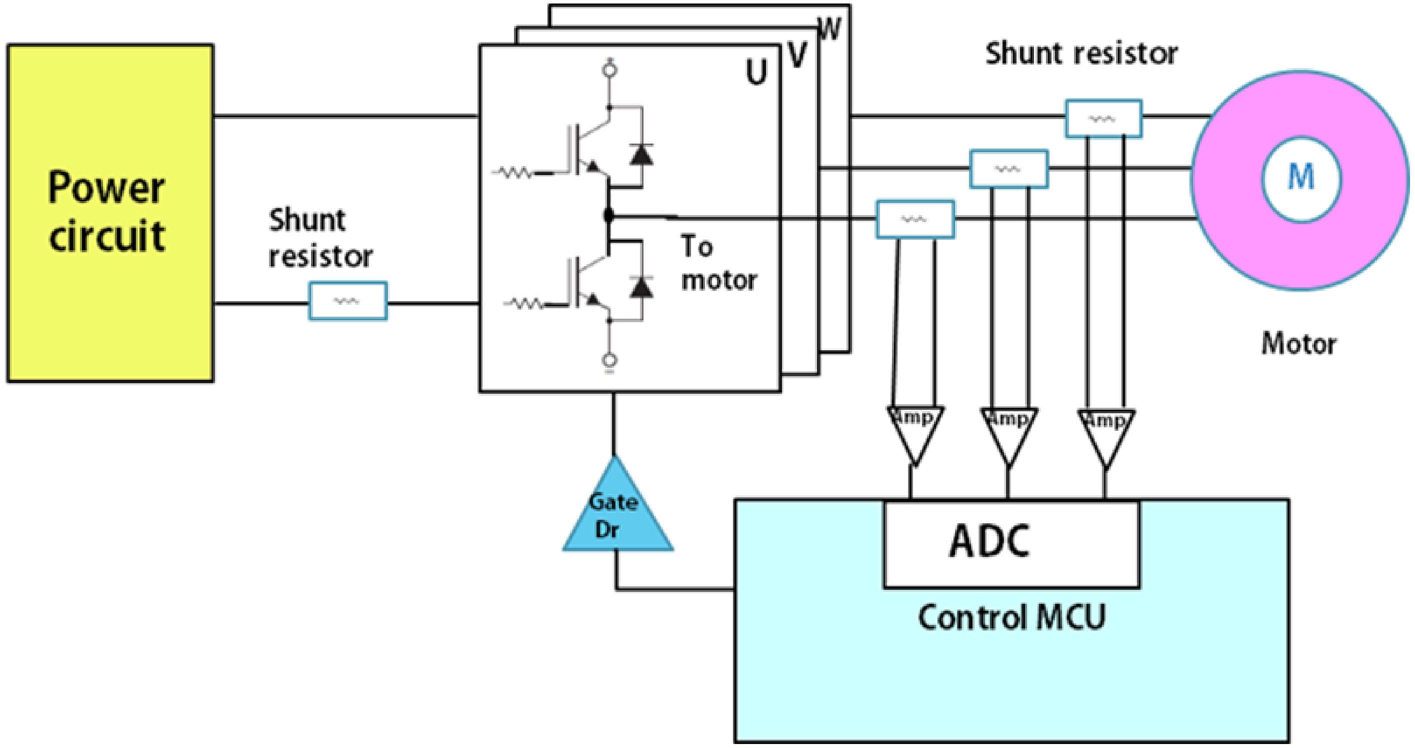
- Voltage and current are critical signals required to operate and control electronic systems
- Voltage can be sensed as high impedance ***without*** "disturbing" the system
- Current sensing often requires breaking the circuit design to insert an additional current sense element

Power Converters: To control you must sense



What component doesn't belong here if we are trying to design a **high-efficiency** power converter?

Motor Drives: To control you must sense



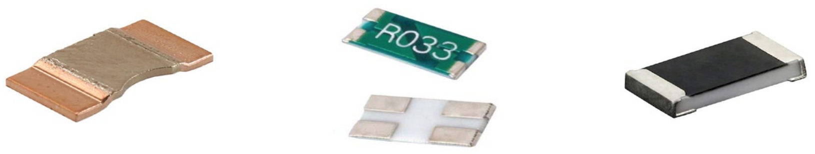
What components do NOT belong here if we are trying to design a **high-efficiency** motor drive?

Sensing current with shunt resistors

Benefits: Accurate, can sense low-value currents, can sense DC currents

Drawbacks:

- Lossy- adding shunt loss element only to create voltage representation of current. Creates thermal challenges. Added source inductance slows turn on/off of switching elements. Tradeoff of accuracy vs. efficiency.
- Complicated- requires additional components, could require isolation, careful design. Can’t easily sense bi-directional current.
- Slow- need to sense, condition signal, convert to digital, process, convert back to analog, act in some cases
- Large, expensive current shunts are needed. May require dedicated bias supplies and additional ICs.

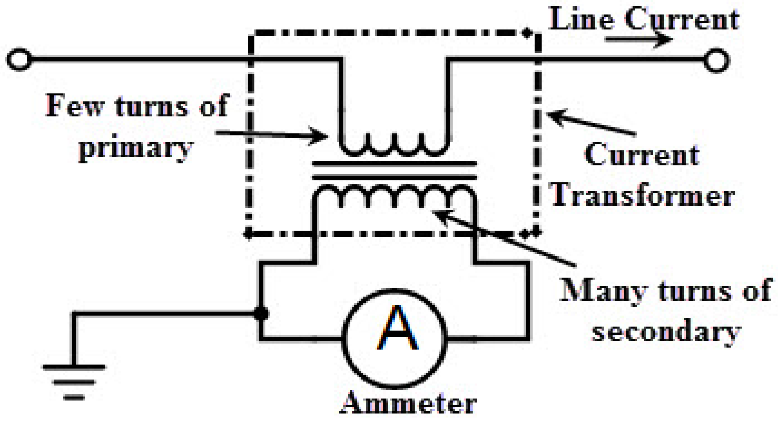


Sensing with current-sense transformers (CTs)

Benefits: Already isolated; can be used for high-side or low side sensing easily, lower power loss for high-current sensing, achieves signal gain with simple turns-ratio, no dedicated bias supply needed, naturally senses bi-directional current

Drawbacks:

- Can't sense DC current
- Duty-cycle limitations to prevent transformer saturation
- Large components; usually toroids

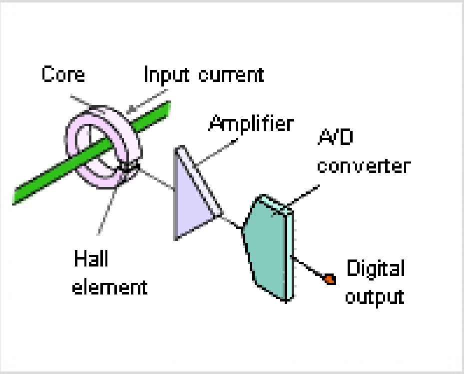


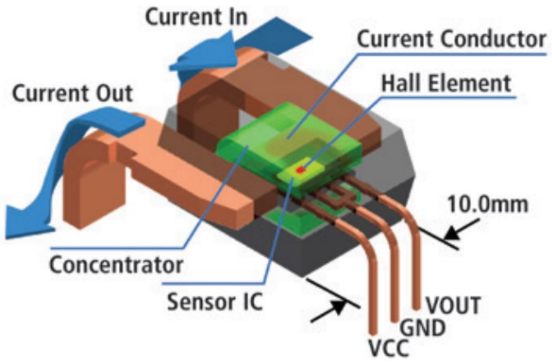
Sensing current with Hall-effect sensors

Benefits: Nearly “lossless”, can measure DC currents

Drawbacks:

- Inaccurate at low current values. Sometimes requires zero-current offset design
- Distorted by external magnetic fields or specific mechanical orientations
- Requires dedicated hall sensor ICs and bias supplies and supporting circuitry
- Usually accurate for only a narrow current range of interest
- Relatively low bandwidth (<100 kHz)
- Comparatively more $ than previous solutions listed



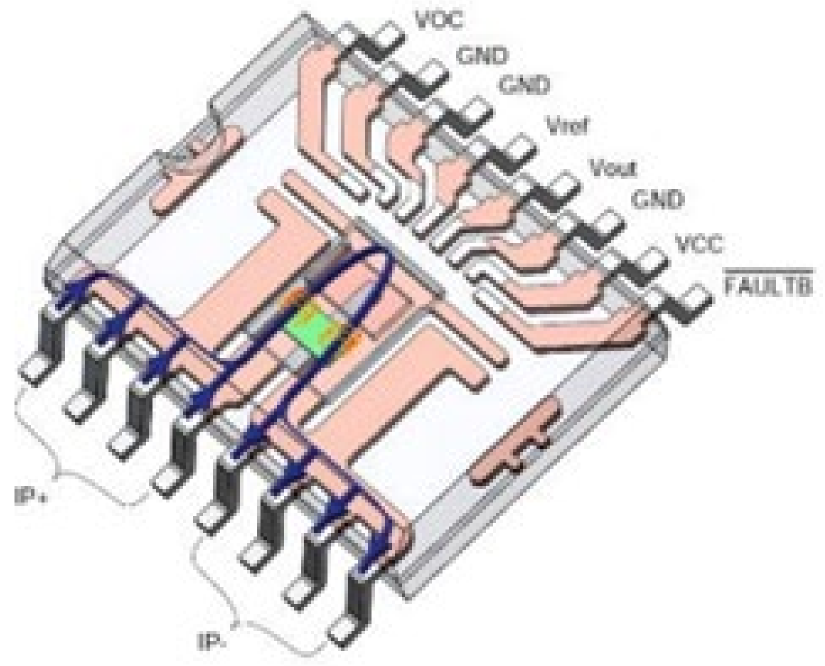


Anisotropic Magneto-Resistive (AMR) Sensing

Benefits: High Bandwidth(1.5MHz+), can measure AC and DC signals, small, resistant to external fields and noise, low offset error

Drawbacks:

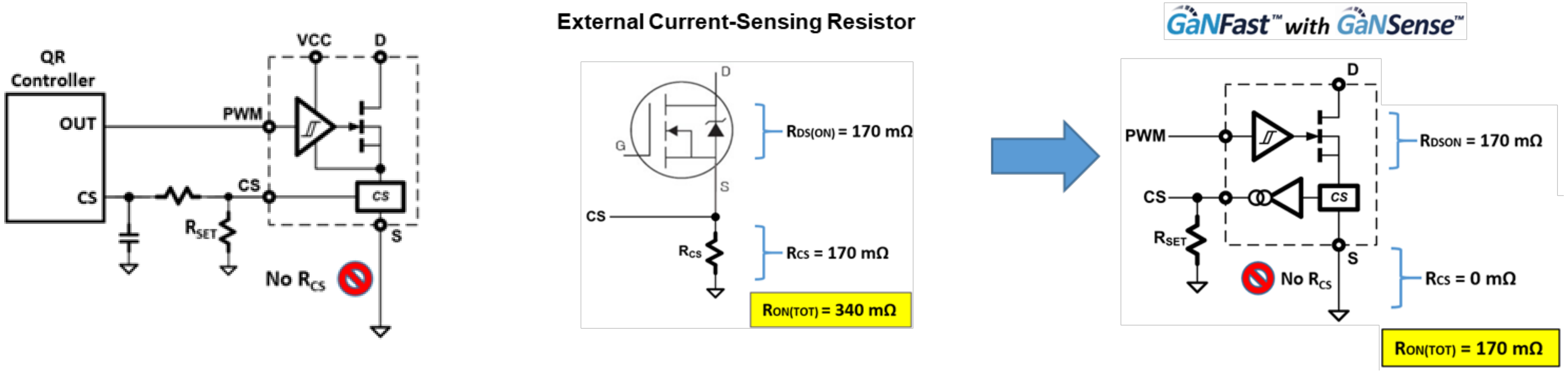
- Dedicated IC required
- Bias supply needed
- New technology, limited vendors
- Comparatively more $ than previous solutions listed



*courtesy of Aceinna

The future of current sensing and the power electronics building block

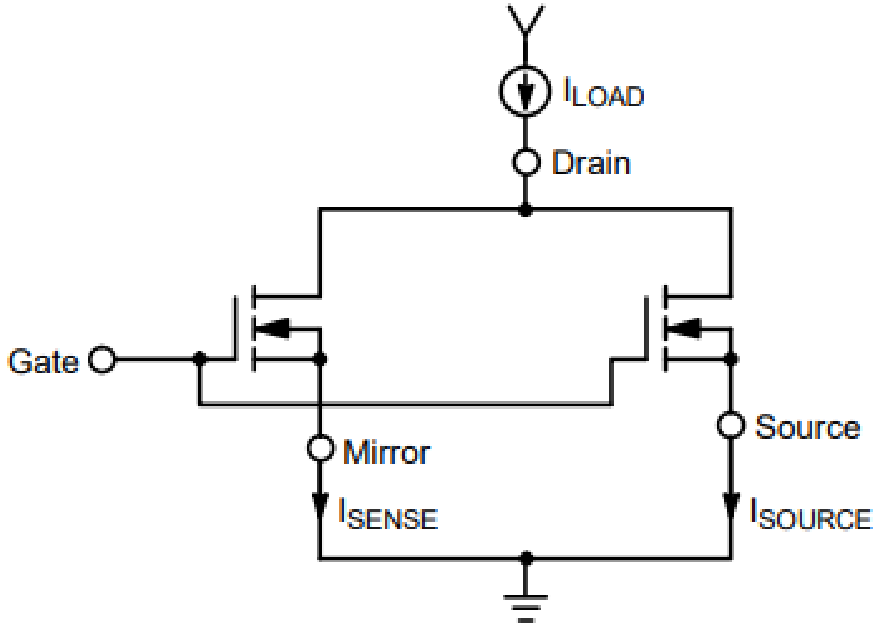
- Integrated “lossless current sensing” built in with the power FET device
- Removes shunt current resistor, hotspot, and parasitic inductance in FET source path
- Removes extra resistance, increases efficiency (Ex. +0.5% for 65 W QR Flyback)
- Localized and accurate; immune to noise/fields/ground-bounce
- Adjustable current limit through external R_{SET} outside power path
- Doesn’t require any additional components or ICs or dedicated bias power



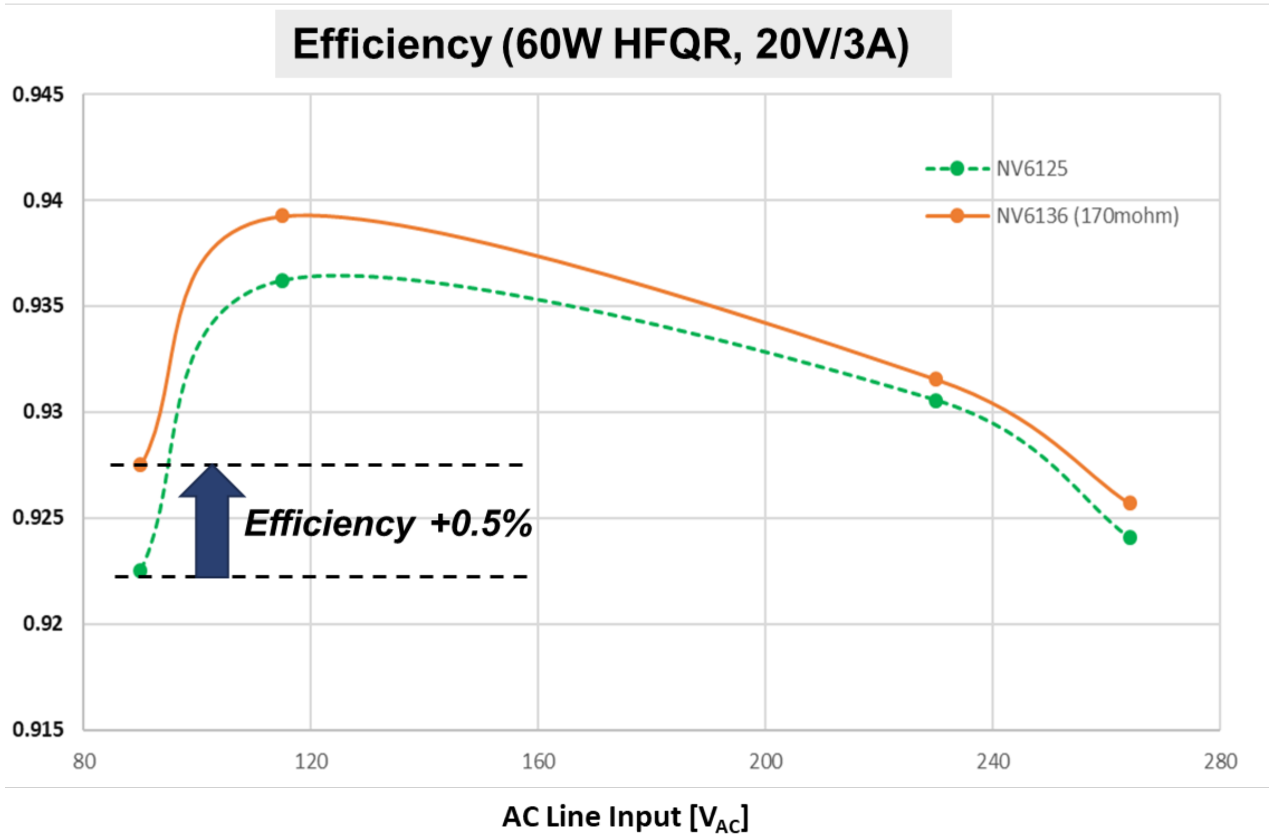
Proven technique reimagined: Current-Mirror

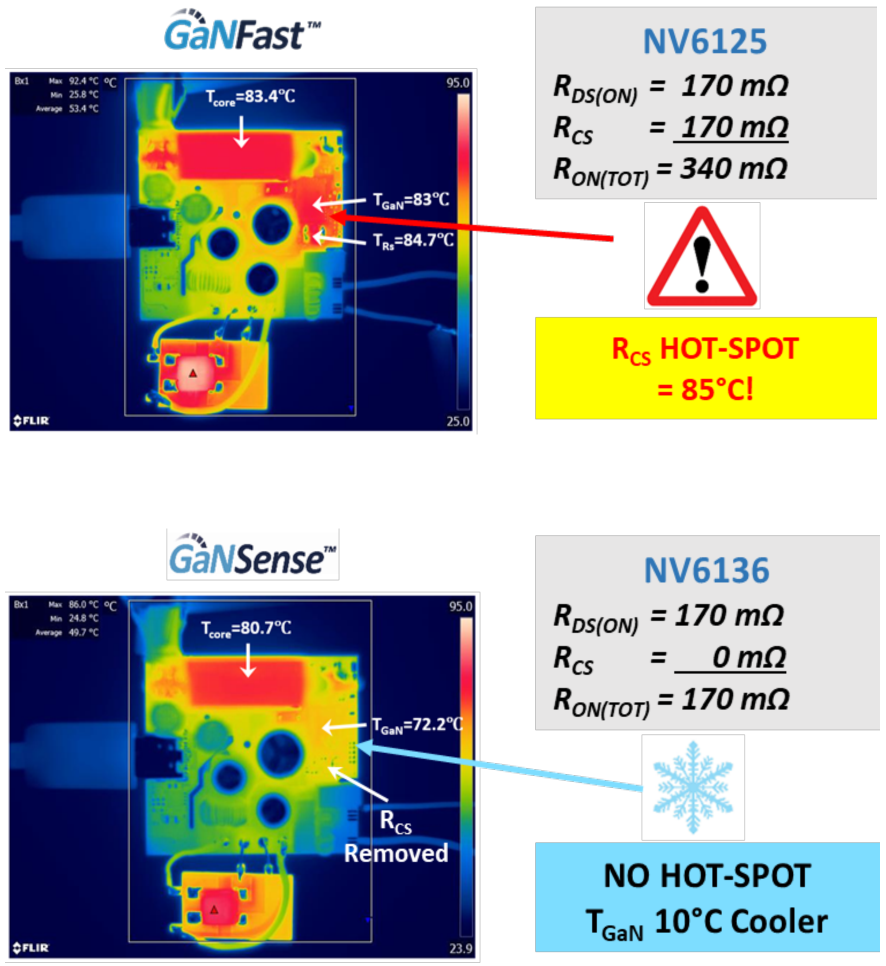
Benefits:

- Small "current-mirror" built in parallel monolithically with main power GaN FET, so-called "GaNSense"
- Negligible size/cost adder
- Well-matched devices. $R_{DS(ON)}$ and temperature effects cancelled out naturally
- Sensing "mirror" FET $R_{DS(ON)}$ ~1000-1500 times larger than main power FET. Negligible power loss.
- I_{SENSE} then becomes ratio of I_{SOURCE} based on $R_{DS(ON)}$.



Higher Efficiency and less heat





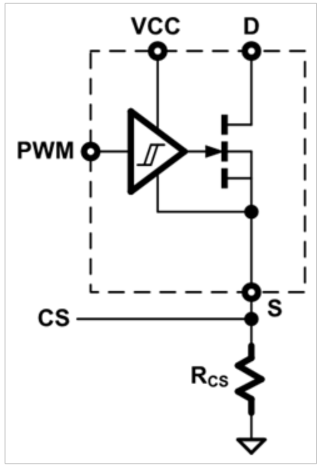
Higher reliability and speed

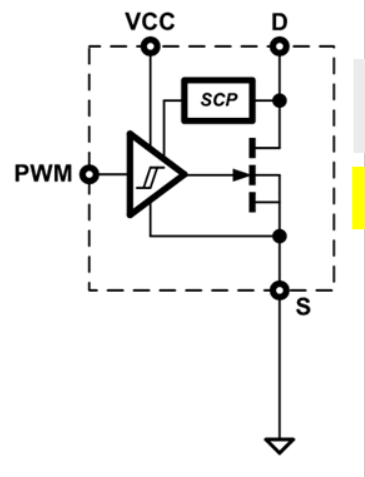
Benefits:

- Localized sense+protection; higher reliability
- Faster; capable to operate at higher frequency

Uses QR controller OCP function

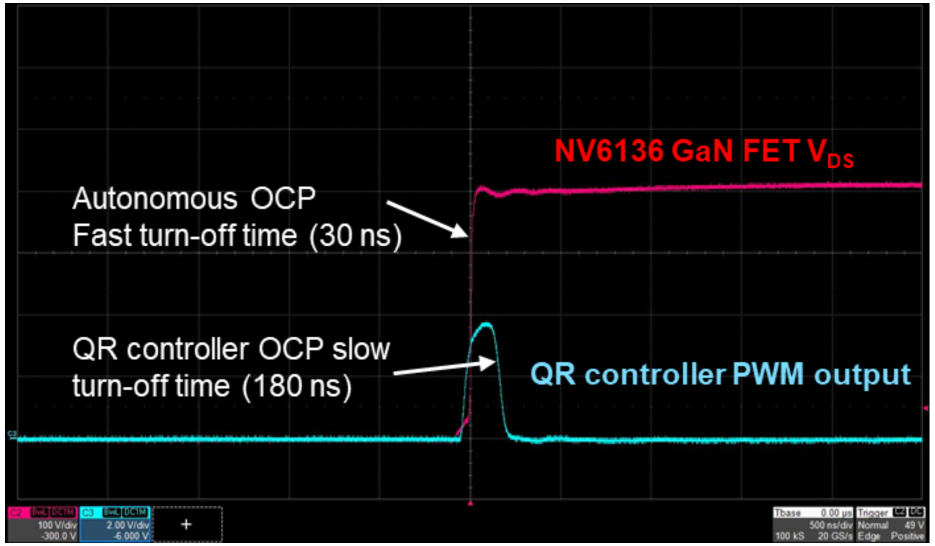
T_{OCP} = 180 ns





Integrated SCP function

T_{OCP} = 30 ns

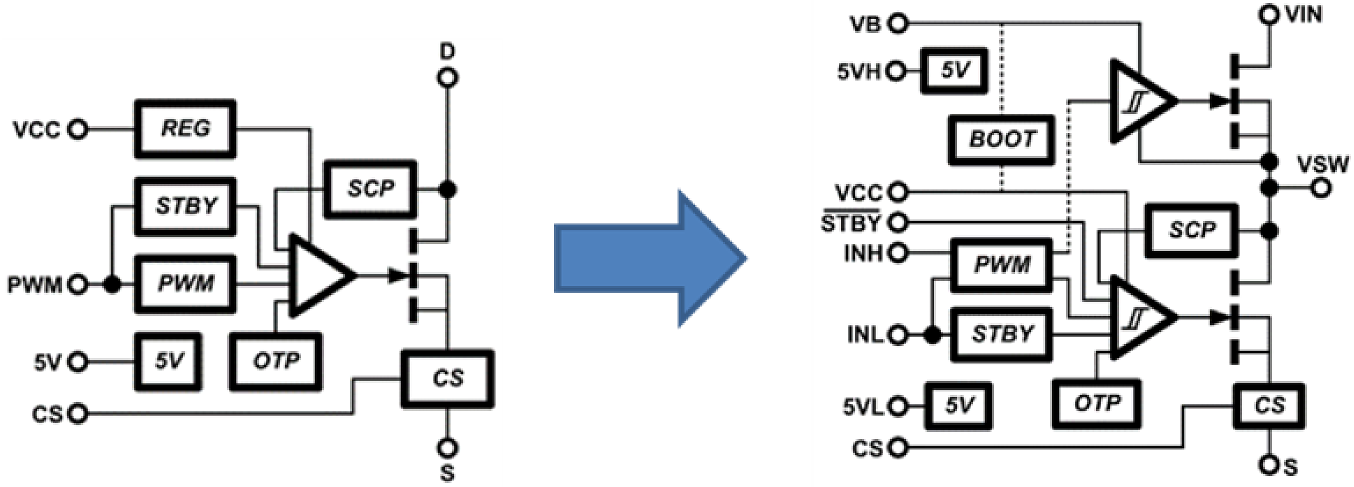


Comparison of current sensing methods

	Bandwidth	Response time	Accuracy	Requires bias supply	Current Range	Power Loss	Relative Size	Sensing cost
Shunt Resistor + OpAmp	kHz-10 MHz	300 ns-1 ms	1-5%	Yes	mA-A	mW-W	Medium	$$
Current Transformer	60 Hz-1 MHz	300 ns-1 ms	3-5%	No	mA-kA	mW	Medium-Large	$$
Hall Effect	kHz-100 kHz	10 us-1 ms	5-10%	Yes	A-kA	mW	Large	$$$
AMR	Hz-1.5 MHz	<300 ns	0.6%-3%	Yes	mA-A	<40mW	Medium	$$$
GaNSense Lossless Current Sensing	Hz-8 MHz	30-100 ns	2%	No	mA-A	<10mW	0	0

Where to next in current sensing?

- Power electronics “building blocks”. Plug-and-play. Offloading central controllers for better accuracy and faster response.
- Higher Levels of integration in 1-switch and 2-switch power converters and motor drives
- Pushing the limits of accuracy/bandwidth/robustness as demands for efficiency and power density continue to increase
- New circuit topologies with high performance WBG power switches demands new current sensing



Thank you for your interest.

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