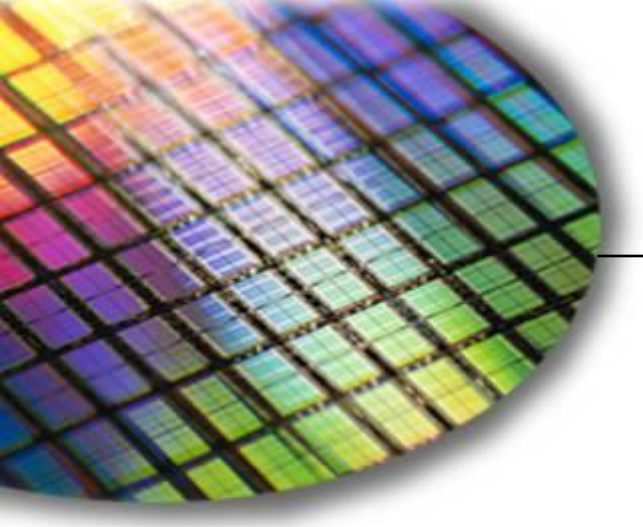


The World Leader in High Performance Signal Processing Solutions

5.1 Fully Integrated Isolated DC-to-DC Converter and Half Bridge Gate Driver with Integral Power Supply

1st International Workshop on Power Supply on Chip
Cork, Ireland

Baoxing Chen
Analog Devices, Inc.
804 Woburn St.
Wilmington, MA 01887

PWR SOC '08

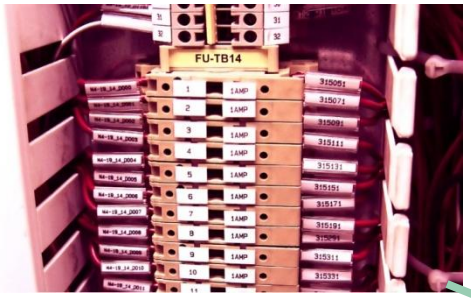
ANALOG DEVICES

Outline

- Integrated Signal and Power Isolation Needs
- Power Converter Architecture
- Transformer Structure
- Converter Performance
- Half Bridge Gate Driver Architecture
- Summary

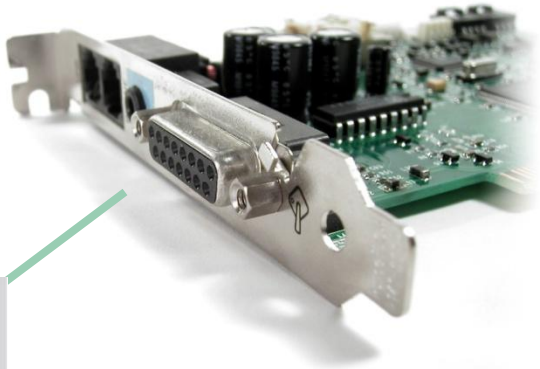
Isolation Applications

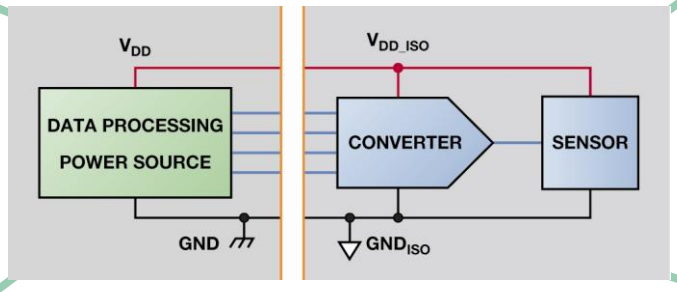
PLC
I/O and Communication



Power Supply

Instrumentation
Data Acquisition and Communication





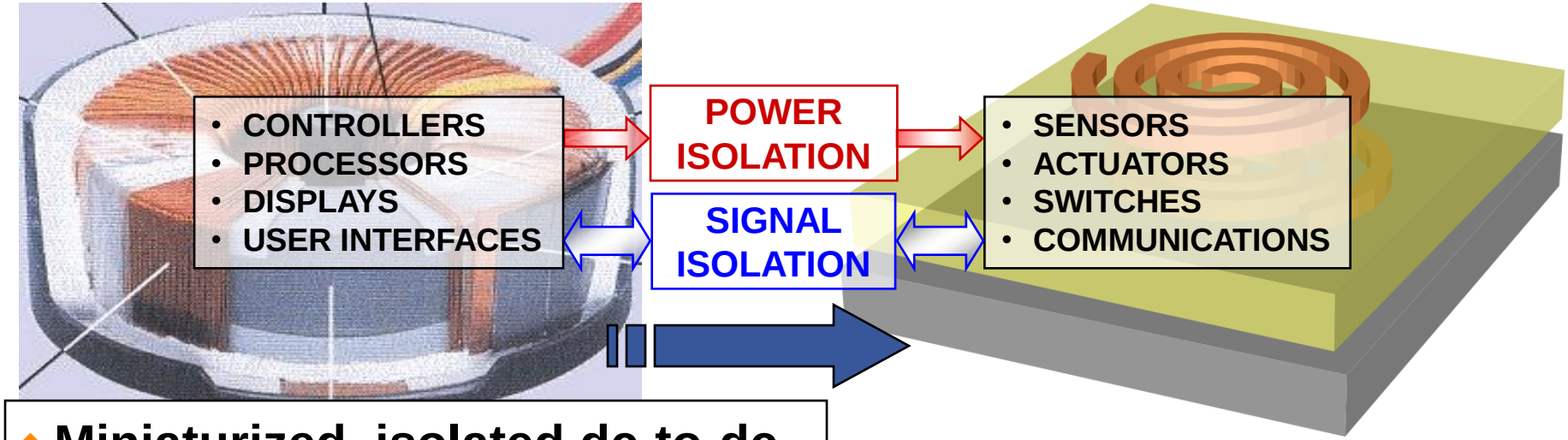
Motor Control
Sensing and Gate Drive

Plasma TV

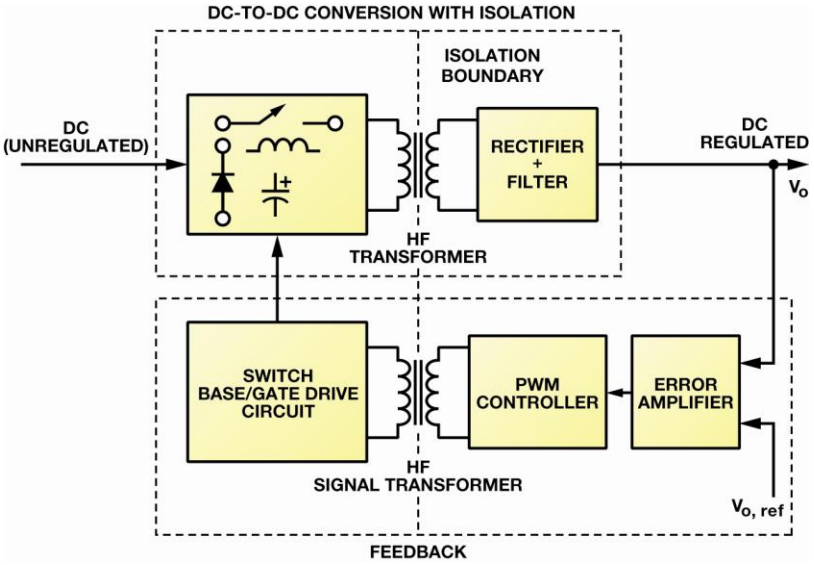
Patient Monitoring
To/From Patient

ANALOG DEVICES

Integrated Isolated Power Transfer Needs

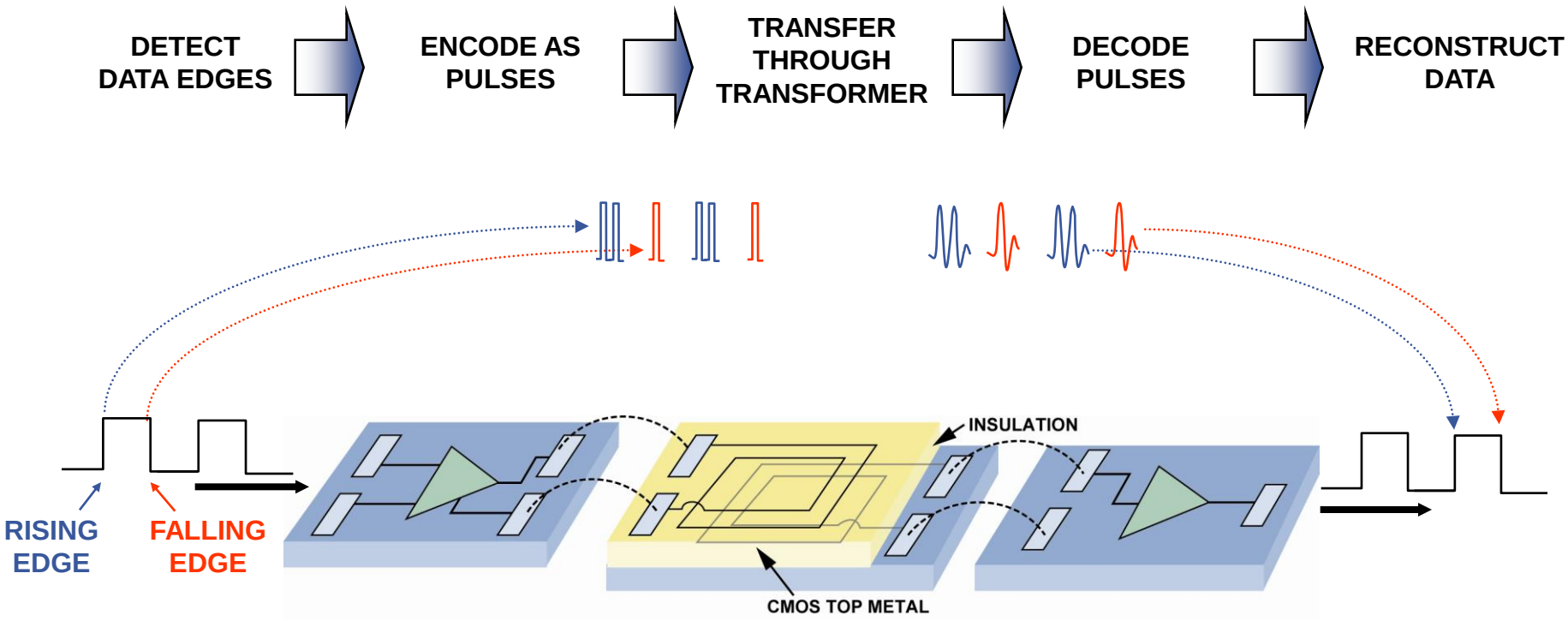


- Miniaturized, isolated dc-to-dc converter
- High frequency energy conversion with low frequency energy regulation
- Energy conversion optimized while regulation maintained through wide input and load ranges



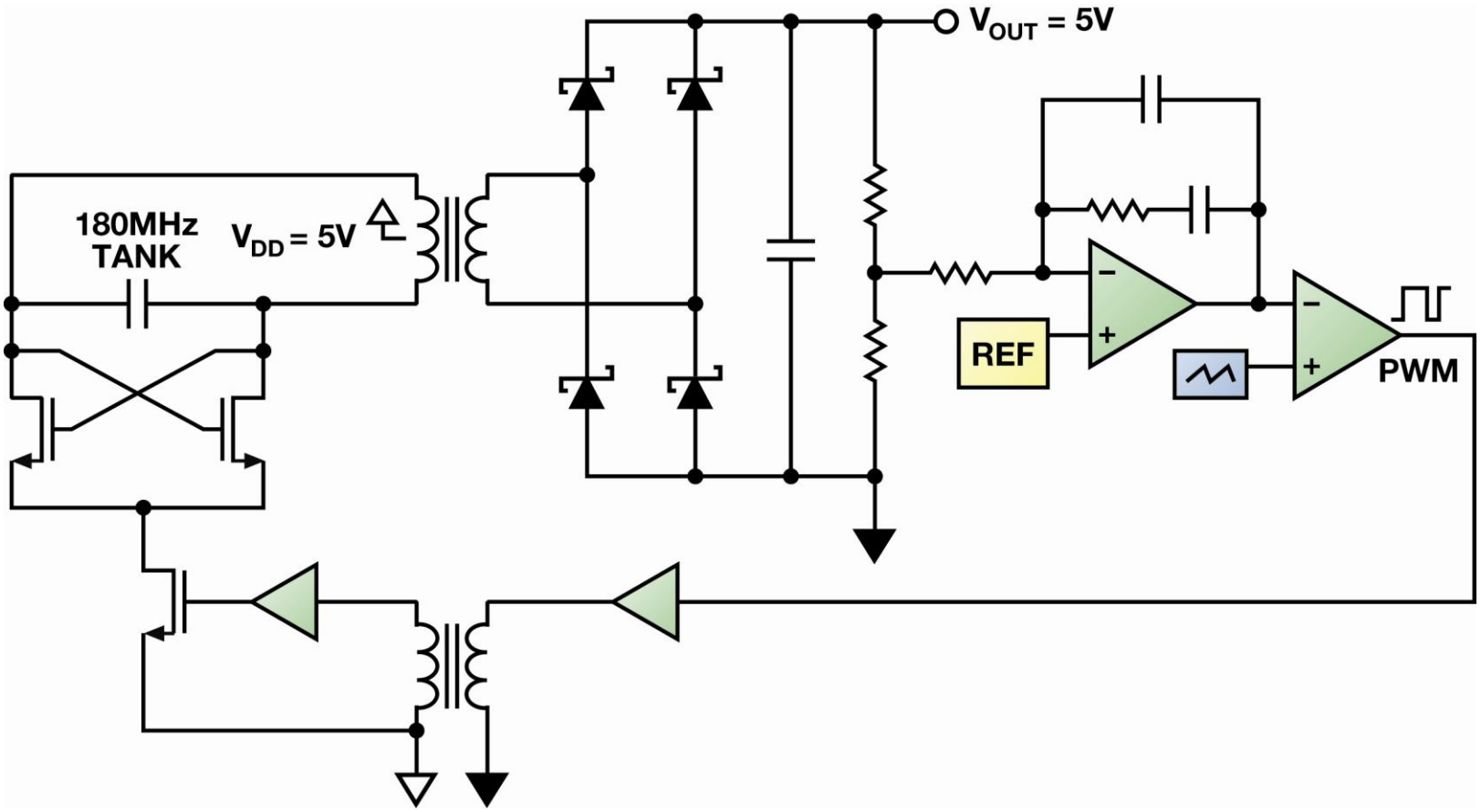
ANALOG DEVICES

Signal Transmission Operational Diagram



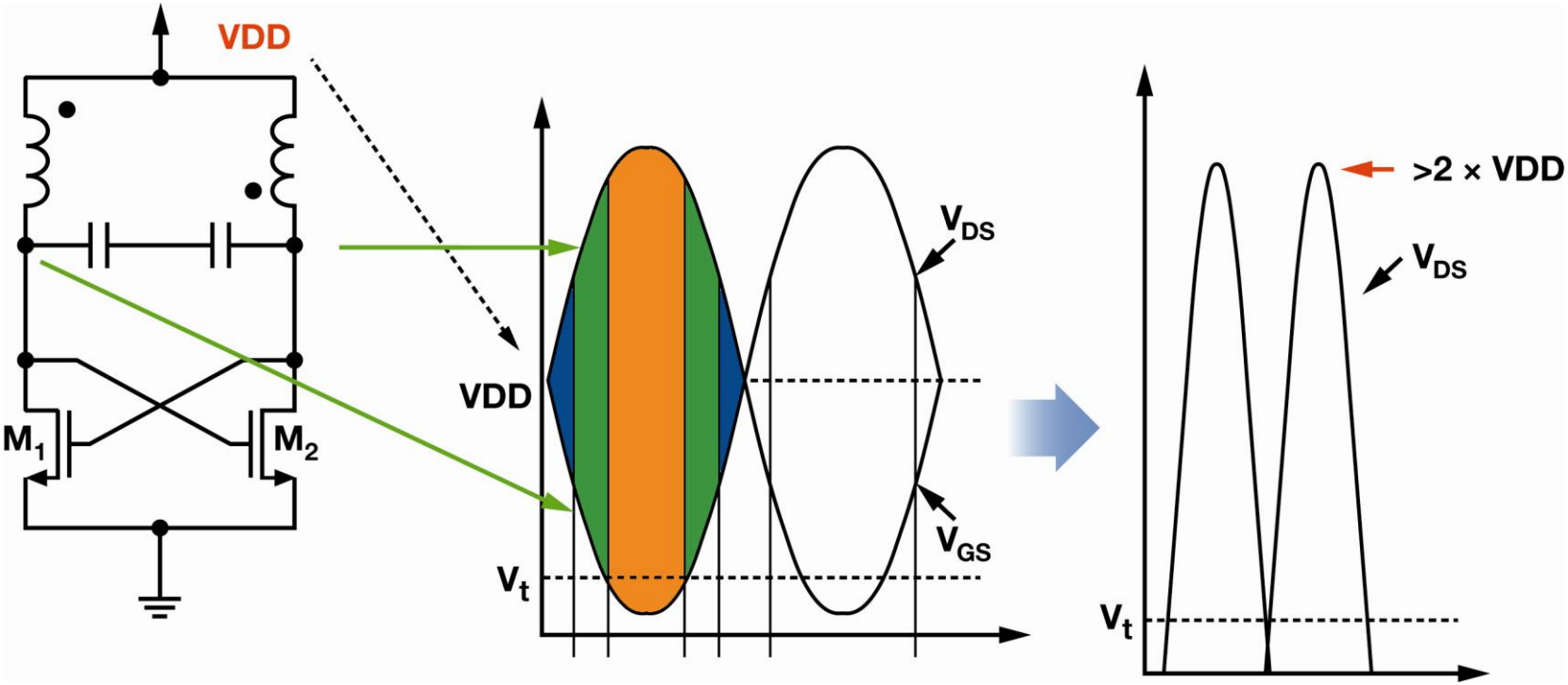
ANALOG DEVICES

DC-to-DC Converter Architecture



ANALOG DEVICES

Primary Switching States: Resonant Gate Drive ZVS



$V1 = VDD + V_1 Cos(\omega t)$.

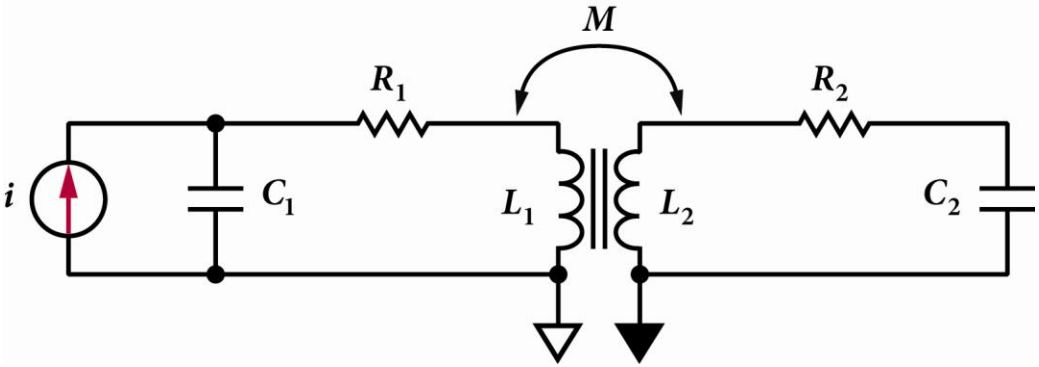
Region I: $V_1 < V_t/2$ both saturated.

Region II: $V_t/2 < V_1 < VDD - V_t$ one linear, and one saturated.

Region III: $VDD - V_t < V_1$ one linear, and the other will be off.

We want region III! Power delivered to load, not MN1/MN2!!!

Transformer-Coupled Resonator



$$\omega_{1,2}^2\Big|^{Transf} = \frac{-(L_1C_1 + L_2C_2) \pm \sqrt{(L_2C_2 + L_1C_1)^2 + 4C_1C_2(M^2 - L_1L_2)}}{2C_1C_2(M^2 - L_1L_2)}$$

$$\omega_1^2\Big|^{Transf} = \frac{1}{(L+M)C} \qquad \omega_2^2\Big|^{Transf} = \frac{1}{(L-M)C}$$

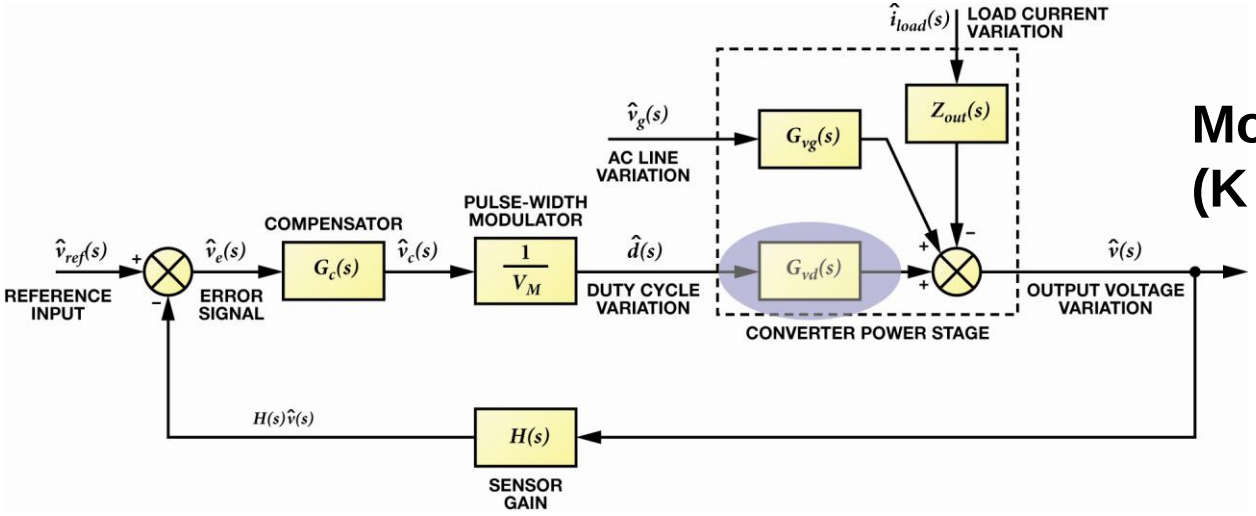
$$Z_{in}(\omega_1)\Big|^{Transf} \approx \frac{L+M}{2rC} \qquad Z_{in}(\omega_2)\Big|^{Transf} \approx \frac{L-M}{2rC}$$

High Q Resonance

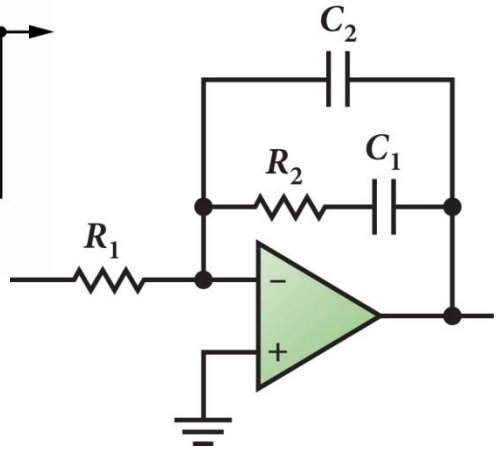
Low Q Resonance

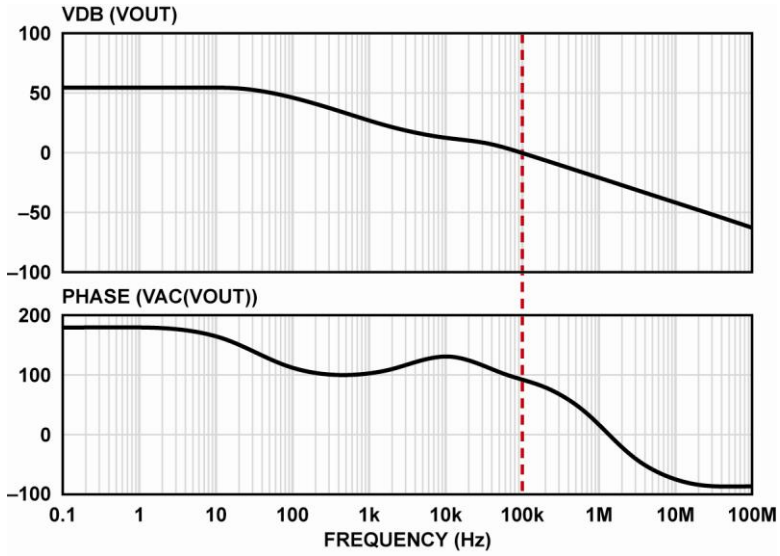
ANALOG DEVICES

Converter Stability



Modified PI Controller (K Factor Type II)



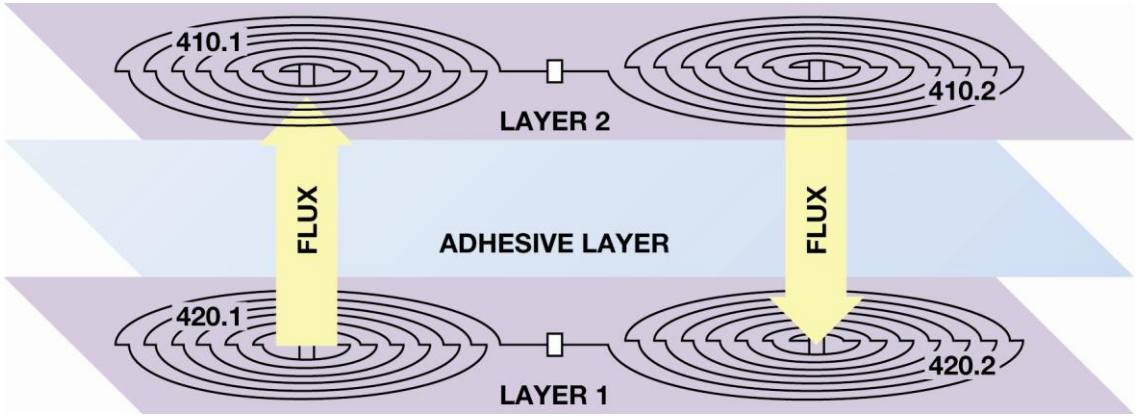


$$G_c = k\frac{1+s\tau}{s\tau}\frac{1}{1+s\tau_p}$$

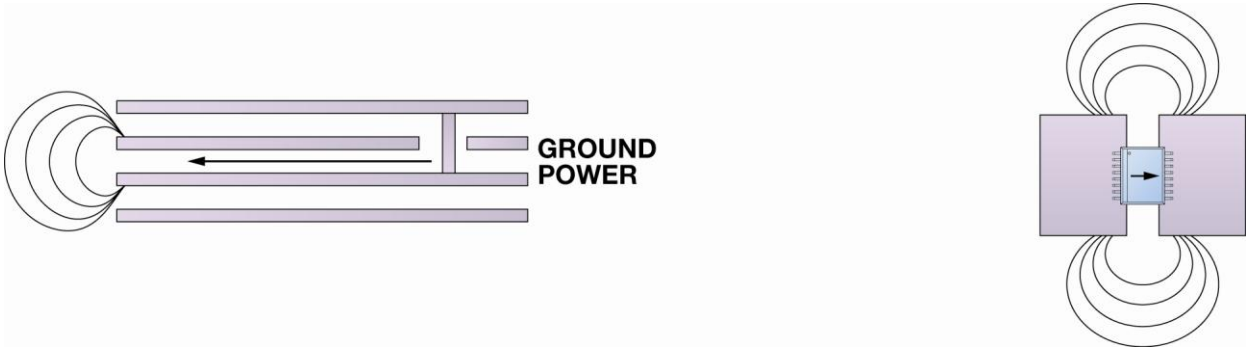
$$k = \frac{R_2C_2}{R_1(C_1+C_2)}; \tau = R_2C_2; \tau_p = \frac{R_2C_1C_2}{C_1+C_2}$$

ANALOG DEVICES

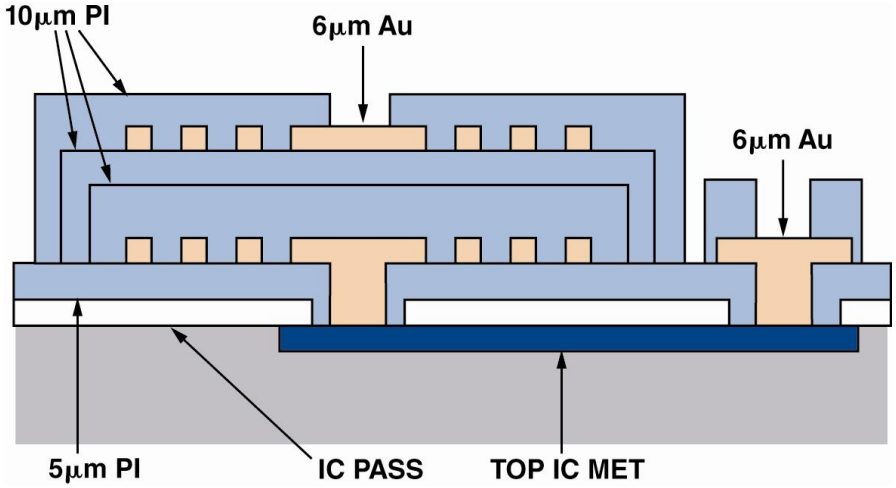
Power Transformer Radiation Minimized Through Antiphase Center Tap



PCB Radiation Dominant-PCB Techniques Available



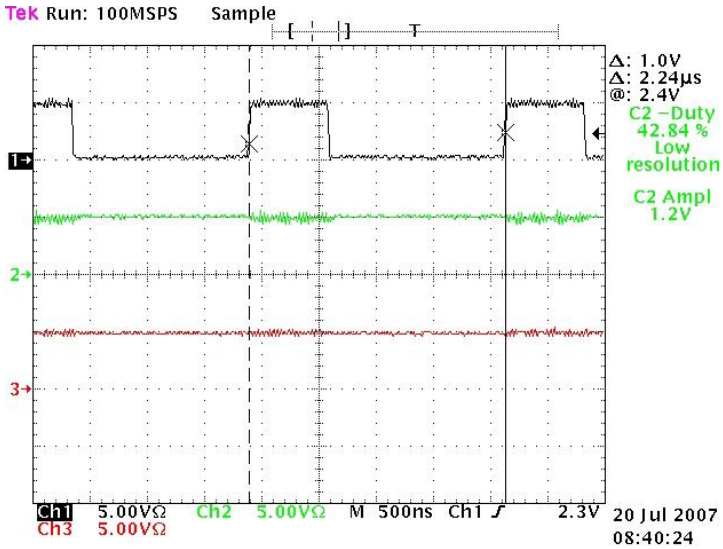
Transformer Structures



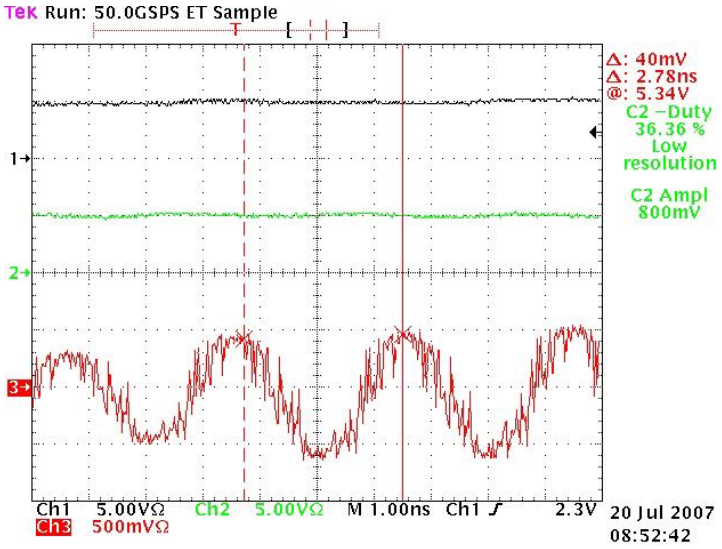
>6 kV rms ISOLATION

- Primary: Two Coils Connected in Center-Tapped
- L = 8 nH, R = 0.8 Ω, Cs = 0.38 pF, Q = 19 at 300 MHz
- Radius = 460 μm, Turns = 3, Width = 60 μm, Space = 7 μm
- Secondary (1:1 for 5 V output): Two Coils Connected in Center-Tapped
- L = 8 nH, R = 0.8 Ω, Cs = 1.2 pF, Q = 13 at 300 MHz
- Radius = 460 μm, Turns = 3, Width = 60 μm, Space = 7 μm

Converter Waveforms



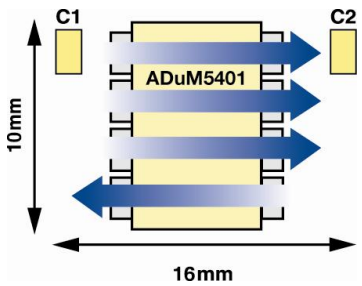
ZOOM-IN

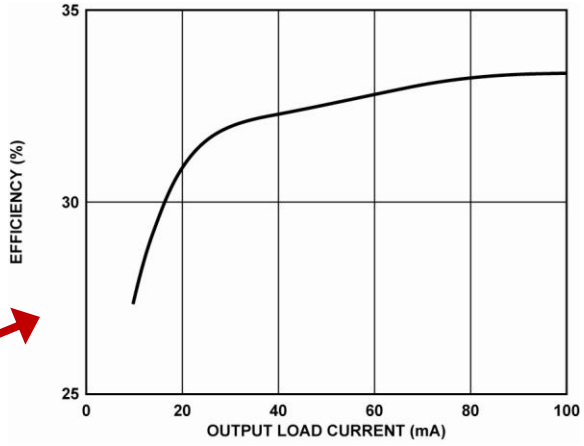


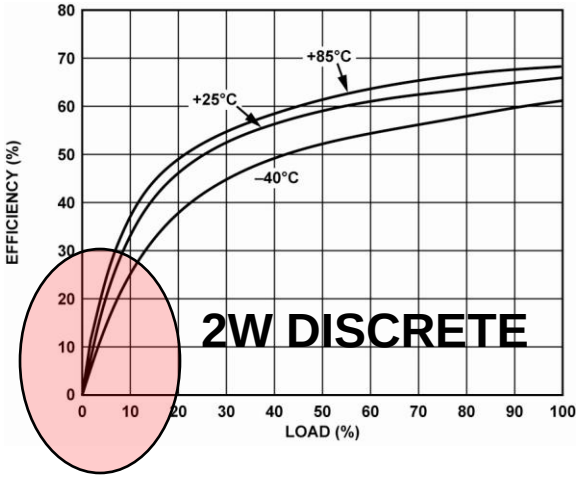
Ch. 1 is the 450 kHz PWM signal.
Ch. 2 is the input supply.
Ch. 3 is the isolated supply output.

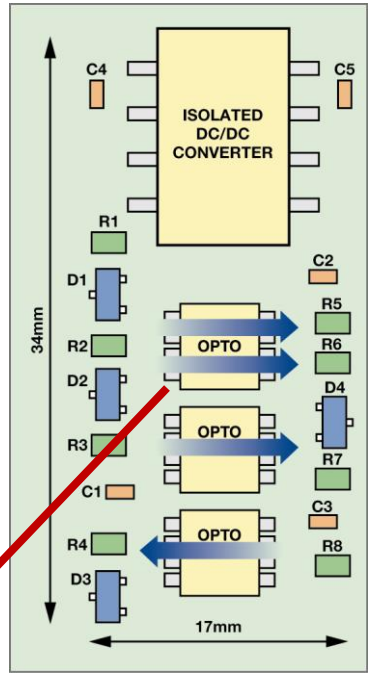
340 MHz Noise => 170 MHz Tank

Converter Performance: Saving Power Compared to Discrete Solution







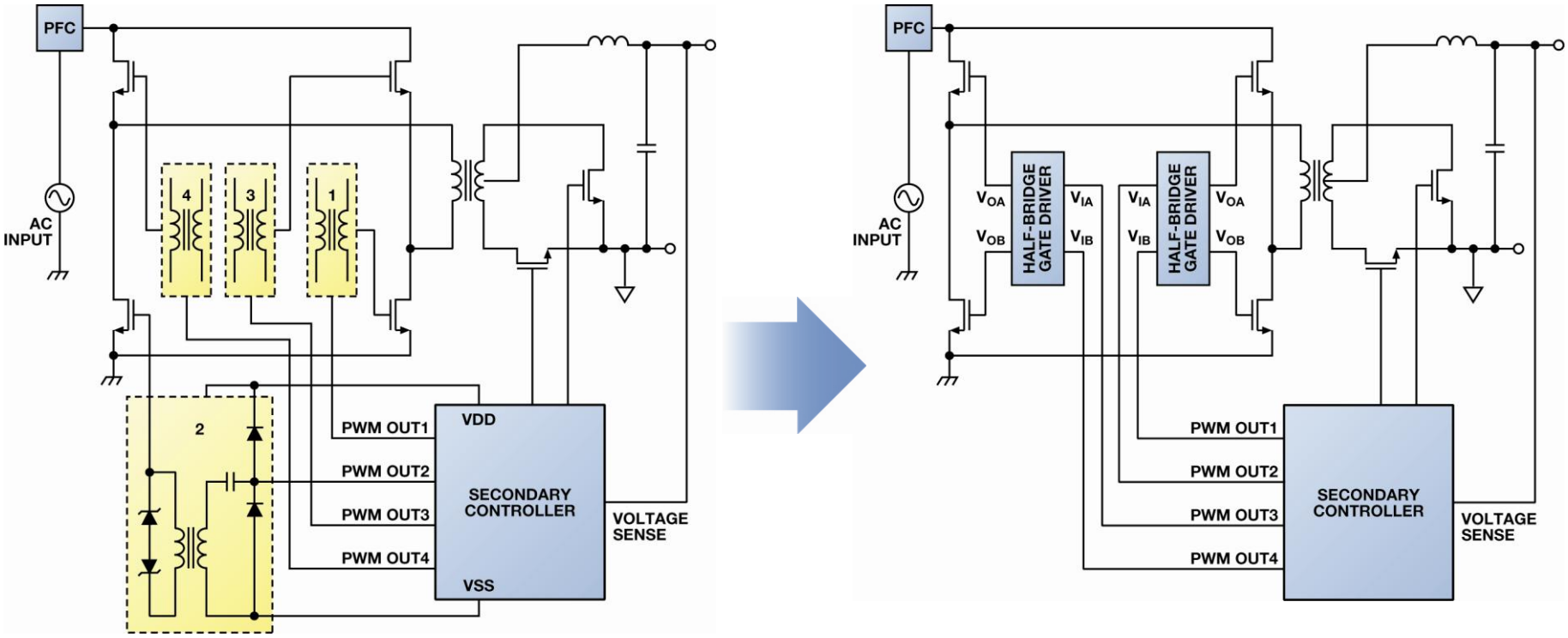


Est. Total Power:	**220 mW**
Supply @ 20 mA Load:	205 mW
*i*Coupler Data:	15 mW

Est. Total Power:	**490 mW**
Supply @ 20 mA Load:	275 mW
Optocoupler Data:	220 mW

ANALOG DEVICES

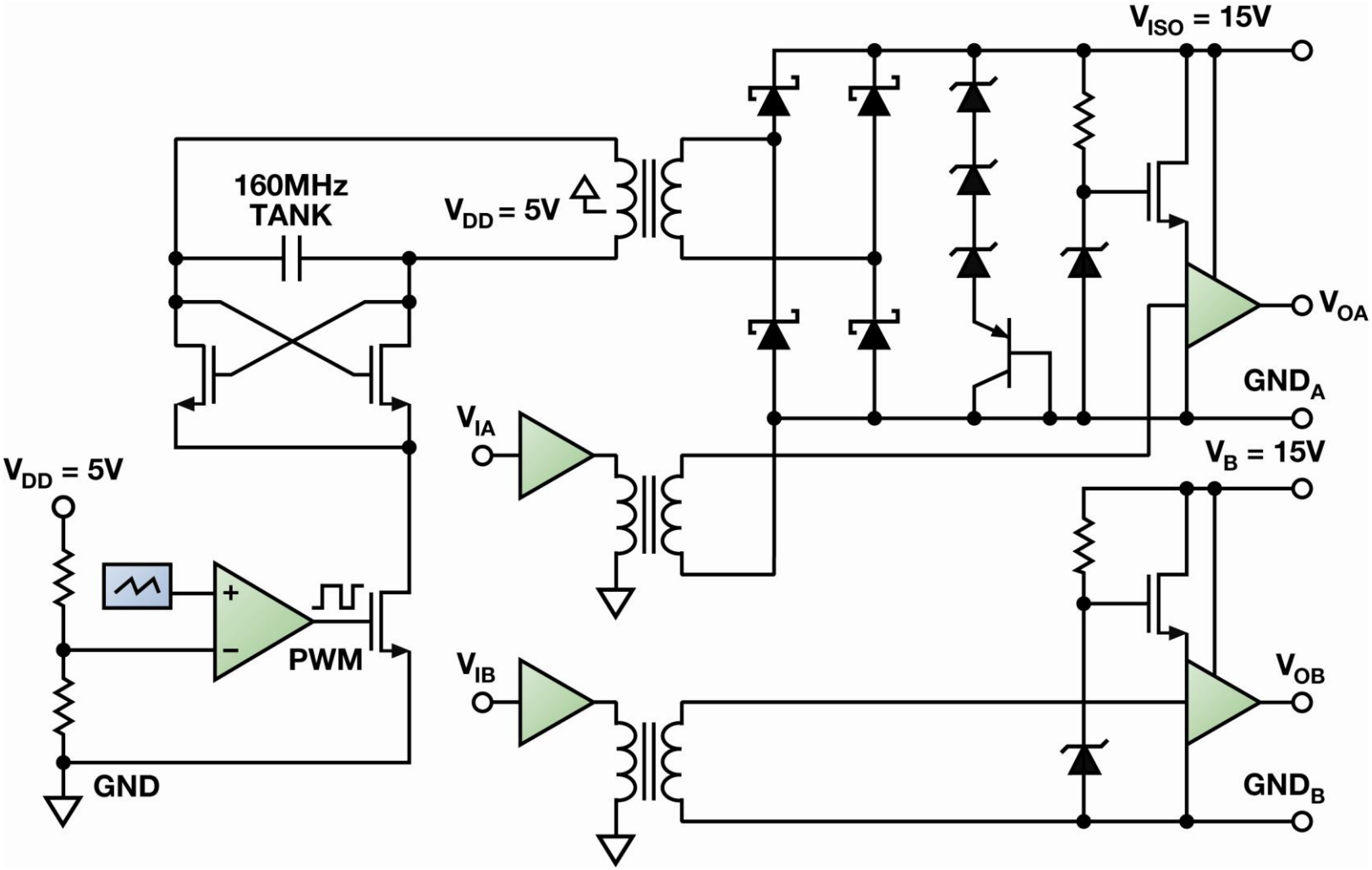
Isolated Gate Drive Integration Needs



Size Reduction, Ease of Use, and Elimination of Duty-Cycle Limitation

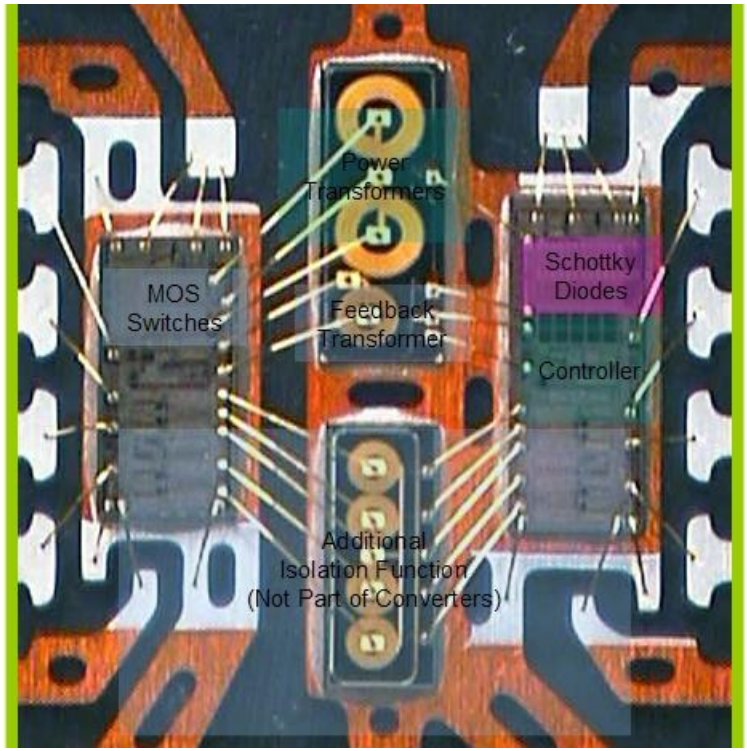
ANALOG DEVICES

Half-Bridge Gate Driver Architecture

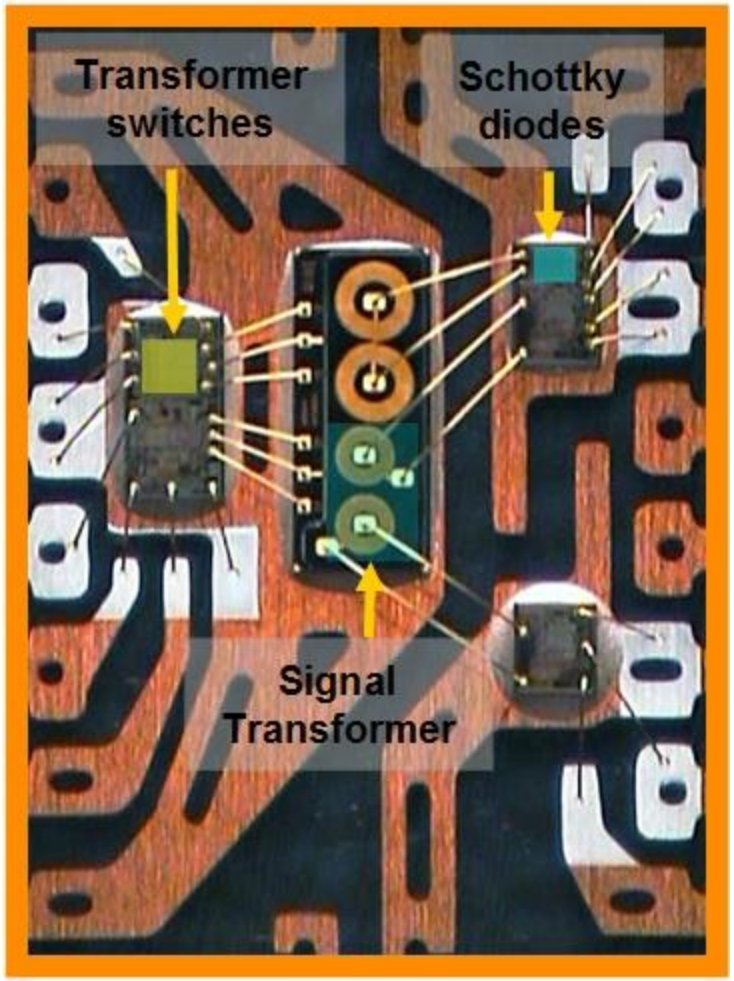


ANALOG DEVICES

500 mW DC-to-DC Converter and Half-Bridge Gate Driver in 16-Lead SOIC



4-Channel Isolation Integrated



Summary

- 500 mW, 33% efficient integrated isolated DC-to-DC converter architecture was reviewed.
- The integrated signal and power integration provide possibilities for total isolated system integration; reduces total system cost and complexity.

Acknowledgement of contribution and assistance from ADI iCoupler group members