Isolation in Power Supply

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The Challenges of Isolation in Power Supply
- Gate Drive Transformer
- Optocoupler

Why use iCoupler Technology

Applications
- DC-DC Power Module
- Automotive
- Inverter
- Isolated Controller

Summary
Isolation in Power Supply

Isolated Signals in a Typical Power Supply

1. PWM Signal
2. Feedback/Error Signal
The challenges of isolation in power supply are sending digital or analog signals across the isolation barrier.

1. **Fast speed**  
2. **Accuracy**  
3. **Compact Size**.

Traditional isolation solutions are:

1. Gate Drive Transformer  
2. Optocoupler
Gate Drive Transformer

Problems in Gate Drive Transformer

1. Core Saturation
2. Complex Design
3. Bulk Size
4. Duty Cycle Limit
Optocoupler

Problems in Optocoupler
1. Low bandwidth
2. Aging Issue
3. CTR with Temp. Variation
4. Power consumption

\[ \text{CTR} = \frac{I_c}{I_F} \]

CTR - Relative Current Transfer Ratio

\( V_{CE} = 5 \text{ V} \)
\( I_E = 5 \text{ mA} \)

\( T_{amb} - \text{Ambient Temperature (°C)} \)
Why use iCoupler Technology?

- **Performance**
  - 4x improvement in data rate and timing specifications

- **Integration**
  - Multiple isolation channel integrated with other functions reduces size and cost

- **Power Consumption**
  - Operates at levels up to 90% lower than optocouplers

- **Ease of Use**
  - Standard digital CMOS interfaces means no external components needed to connect to other digital devices

- **Reliability / Safety**
  - Eliminate LEDs used in optocouplers
Applications – DC/DC Power Module

Small Size For Space Critical Application
Applications – Automotive Power Supply

400Vin 12V/50A For Automotive

High Reliability

Isolated Gate Driver
3 Phase GaN Inverter
- Better Power efficiency
- Higher Power Densities
- Smaller form factor, reduced weight
- Increased Switching Frequencies

Applications – 3 Phase GaN Inverter
Applications – 3 Phase GaN Inverter

Next generation inverters will utilize advanced switching technologies GaN and SiC.

Isolated Gate Driver
Applications – Isolated Controller

BREAK THROUGH THE ISOLATION BARRIER

Industry’s First Isolated Current Mode Controller

- Highly Reliable and Efficient Power Supplies with Integrated Isolation
- Enables Reduced Component Footprint and BOM Cost
- Fast Transient Response Allows Reduced Output Capacitance
- System-Level Benefits Such as Light Load Mode and PGOOD

ANALOG DEVICES
AHEAD OF WHAT’S POSSIBLE™
Applications – Isolated Controller

ADP1074 – Active Clamp Forward with SR Gate Drivers
ADP1071/72 – Flyback/Forward Versions with SR

ADP1074 LGA package in 1/8th brick module
APPLICATION IMPACT
THE PROBLEM WITH OPTO-COUPLERS

OPTO-COUPLERS
► Current Transfer Ratio (CTR) degradation
► Limited bandwidth ~25kHz
► Size is somewhat large with minimal integration
► High temperature opto-couplers are expensive.
► Parameters vary greatly based on operating condition ($I_F$, $R_L$, $T_A$). Can counter with dual optos.

iCOUPLERS
► No gain degradation
► Typically ~400kHz bandwidth
► Size is small or comparable but high integration is possible for SoC
► Temperature stable
► Virtually same across PVT due to digital nature
Customer Value Proposition

► Eliminate Opto Current Transfer Ratio (CTR) Degradation
  ▪ CTR degradation can be up to 50% over life/temperature
  ▪ CTR has a 2X initial variation at Room Temp

► Efficiency
  ▪ Synchronous rectification
  ▪ Adjustable dead-time
  ▪ Light load modes

► Power Density
  ▪ Significant component integration
  ▪ Constant gain/CTR and higher iCoupler speed enable higher BW
  ▪ Allows system to operate at higher switching frequencies with smaller output filtering

► Ease of Use
  ▪ Level of integration makes isolated design more accessible
  ▪ CTR selection variation and degradation makes traditional optocoupler based design difficult
  ▪ Facilitate and accelerate the migration to embedded designs in I&I & CIFR

CTR = \frac{I_c}{I_F}
Customer Value Proposition
Eliminating OptoCoupler Limitations

► Optocouplers have an initial CTR spread of X2 at 25C
  • Numbers are not specified over the temp range

**Transfer Characteristics** (\(T_A = 25^\circ \text{C Unless otherwise specified.}\))

<table>
<thead>
<tr>
<th>DC Characteristics</th>
<th>Test Conditions</th>
<th>Symbol</th>
<th>Device</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Transfer Ratio, Collector to Emitter</td>
<td>(I_f = 10 \text{ mA}, V_{CE} = 5 \text{ V})</td>
<td>CTR</td>
<td>CNY17-1/1-M</td>
<td>40</td>
<td>80</td>
<td></td>
<td>%</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>CNY17-2/2-M</td>
<td>63</td>
<td>125</td>
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<td>%</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>CNY17-3/3-M</td>
<td>100</td>
<td>200</td>
<td></td>
<td>%</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>CNY17-4</td>
<td>160</td>
<td>320</td>
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<td>%</td>
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</tbody>
</table>

- For transient response, designer must assume worst case min. CTR value to meet spec.
- Low bandwidth, poor transient response. Adding more \(C_{out}\) does not necessarily help
- For stability, designer must assume worst case max. CTR value.
- Impacts phase margin and stability
Focus on CTR Ageing:

LEDs CTR wear-out with use
- Light output degrades with operating time

Wear-out accelerated by
- Increased current
- Elevated temperature
  - Most are rated to 85°C
  - Higher temperature ratings increase price and reduce speed

CTR reduction up to 50% results in deterioration in bandwidth and transient response

Digital Isolator Transfer Characteristics do not Change Over Time

Note: Internal temperature likely to be ~20°C higher than above
High Bandwidth Control Loop

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Summary

Compared with traditional optocoupler and gate drive transformer solutions, Analog Devices’ iCoupler Technology provide a more reliable, high bandwidth and small size isolation solution in power supply.