Isolation Techniques Without an Isolator

Anthony T. Huynh, Maxim Integrated
Principal Member of Technical Staff, Applications Engineering
APEC 2018
Outline

- Isolation Overview
- Isolator Technologies
- Isolation Techniques for Power Path Feedback Loop
- Summary
Why do we need isolation?
Isolation for signal path, power path
Safety regulatory and compliance standards
Why Do We Need Isolation?

Safety
• Prevents current surges from damaging equipment
• Protects humans from mains voltage

Avoid Ground Loops
• Avoids disruptive ground loops where different ground potentials are involved
• Isolates digital noise from precision analog system

Level Shifting
• Generates multiple isolated positive and/or negative outputs
Isolation for Signal Path & Power Path

Analog I/O Module

- Analog Input
  - OVP
  - AMP
  - MUX
  - PGA
  - ADC
- Analog Output
  - AMP
  - DAC
  - Isolation Barrier

Control Unit

- Isolated Power
- DC-DC Converters
  - Various voltages from 1.0V to 3.3V
- CPU
- FPGA

24V Bus

Maxim Integrated
Safety Regulatory and Compliance Standards

Component level standards
- UL1577: Optical Isolators
- VDE V 0884-10: Magnetic and capacitive couplers for safe isolation
- VDE V 0884-11: Magnetic and capacitive coupler for basic and reinforced isolation

All isolator manufacturers follow safety standards and certification

Equipment level standards
- IEC 61000-4: Electromagnetic Compatibility (EMC) Test Standards
- IEC 60950-1: Information Technology Equipment – Safety
- IEC 60601-1: Medical Electrical Equipment
- IEC 61010-1: Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use
Outline

Isolation Overview

Isolator Technologies

Isolation Techniques for Power Path Feedback Loop

Summary

- Analog: Optical
- Digital: Optical, magnetic, and capacitive
- Isolation for signal path example
Analog Optical Isolator

Analog current is reflected to the isolated side, measured as current transfer ratio, CTR

\[
CTR = \frac{I_c}{I_d}
\]
Digital Isolators: Optical and Magnetic

Optical

Magnetic

Input

Output

Vcc1

GND1

Vcc2

GND2
Digital Isolator: Capacitive

Modulator-based
Digital Isolator: Capacitive

Edge-based

- Edge based differential
- Best for low prop delay, low jitter, and low power
## Digital Isolator: Edge-Based Capacitive vs. Optocoupler

<table>
<thead>
<tr>
<th># Chs</th>
<th>Data Rate</th>
<th>Prop’ Delay (max)</th>
<th>Prop’ Delay Skew (max)</th>
<th>Supply-Current/Channel</th>
<th>CMTI</th>
<th>Iso Voltage $V_{ISO}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAX14435FAWE</td>
<td>4</td>
<td>150Mbps</td>
<td>10ns</td>
<td>2ns</td>
<td>0.6mA</td>
<td>50kV/µs</td>
</tr>
<tr>
<td>Leading Optocoupler</td>
<td>1</td>
<td>50Mbps</td>
<td>22ns</td>
<td>16ns</td>
<td>15mA</td>
<td>10kV/µs</td>
</tr>
</tbody>
</table>

### Optocoupler Prop Delay Definition

![Optocoupler Prop Delay Definition](image1.png)

### Other Digital ISO Propagation Delay Definition

![Other Digital ISO Propagation Delay Definition](image2.png)
## Digital Isolation Technology Comparison Summary

<table>
<thead>
<tr>
<th>Isolator Type</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inductive</td>
<td>Inherently good CMTI performance</td>
</tr>
<tr>
<td></td>
<td>Low power at low data rates</td>
</tr>
<tr>
<td>Optical</td>
<td>Thicker insulation for fail safe applications (e.g. motor drives)</td>
</tr>
<tr>
<td></td>
<td>High working voltage</td>
</tr>
<tr>
<td>Capacitive</td>
<td>Fastest data transmission rates (200Mbps)</td>
</tr>
<tr>
<td></td>
<td>Good immunity to magnetic fields</td>
</tr>
<tr>
<td></td>
<td>Low power at low and high data rates (Maxim’s edge based)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Susceptible to magnetic field interference</td>
</tr>
<tr>
<td>High Power at high data rates</td>
</tr>
<tr>
<td>Slower data transmission rates</td>
</tr>
<tr>
<td>Relatively high power dissipation</td>
</tr>
<tr>
<td>Large performance variation over temperature</td>
</tr>
<tr>
<td>LED degradation over time</td>
</tr>
<tr>
<td>Low CMTI</td>
</tr>
<tr>
<td>Susceptible to electric field interference</td>
</tr>
<tr>
<td>Good CMTI performance requires extra circuitry</td>
</tr>
</tbody>
</table>

13 | Maxim Integrated
Outline

- Isolation Overview
- Isolator Technologies
- Isolation Techniques for Power Path Feedback Loop
- Summary

- Analog isolation example
- Digital isolation example
- Isolation without an isolator examples
  > No-Opto Flyback
  > Iso-Buck
**Generic Isolated Power Supply**

Analog feedback loop

Conventional Isolated DC-DC converters need:

- Isolation transformer
- Secondary side Error Amp
- Opto-coupler
- Discrete components to couple the feedback signal across the isolation boundary

Digital feedback loop replaces:

- Opto-coupler w/ digital isolator
- Error Amp w/ ADC, DAC & Digital Control Core
Feedback Loop Isolation Without Isolator – No-Opto Flyback

Primary side sensing eliminates opto-coupler and related feedback circuitry

Classic Flyback with Opto-Coupler Feedback

\[ V_{PRY} = K \cdot V_o \]

\[ V_{IN} \]

\[ N_{DRV} \]

\[ Q \]

\[ I_{FB} \]

\[ R_{FB} \]

\[ \text{Opto-coupler} \]

Error Amp And Reference

No-Opto Flyback

\[ V_{PRY} = K \cdot V_o \]

\[ V_{IN} \]

\[ N_{DRV} \]

\[ Q \]

\[ I_{FB} \]

\[ R_{FB} \]

\[ \text{Opto-coupler} \]

\[ K = \frac{N_p}{N_s} \]
Eliminating Opto-Coupler Saves 30% Area
Opto-Coupler and Error Amp circuitry eliminated
No-Opto Flyback Operating Waveforms

\[ K = \frac{Np}{Ns} \]

\[ V_{in} \times T1 = K \cdot V_o \times T2 \]
60V, No-Opto Isolated Flyback Controller

Benefits
- Simple magnetics – no feedback winding
- Enhanced reliability due to Opto elimination
- Low component count – 50% lower
- Smaller Solution size – 30% smaller

Features
- 4.5V to 60V operating supply
- No OPTO-coupler or 3rd winding needed
- +/- 5% $V_{OUT}$ load and line regulation (typ)
- 2A/4A peak source/sink gate drive
- 50kHz to 250kHz Programmable Fsw
- -40°C to 125°C operation
Feedback Loop Isolation Without Isolator – Iso-Buck

Standard synchronous buck

Iso-buck
High-Efficiency, Isolated “Iso-Buck” DC-DC Converter
4.5V to 42V input

Benefits

- Low component count (Int. Sync FETs)
- Simple transformer – no bias winding
- Small solution size
- Robust protection scheme

Features

- Wide 4.5V to 42V input voltage
- 0.9V to 92% $V_{IN}$ output voltage
- Up to 5W output power
- Built-in primary O/P voltage monitoring
- 10Ld 2x3 TDFN

Delivers up to 5W of power

Typical operating circuit

MAX17681
Outline

Isolation Overview

Isolator Technologies

Isolation Techniques for Power Path Feedback Loop

Summary

• Why isolation is needed?
• Isolation for signal and power paths
• Review of regulatory standards
• Review of isolator technologies: Optical, magnetic, and capacitive
• No-isolator techniques for power supply feedback loops: No-Opto Flyback & Iso-Buck
Anthony T. Huynh
Thong.Huynh@Maximintegrated.com
Thank You!