Isolated Power Supplies for PLC I/O Modules

Industrial Systems - Factory Automation and Control

Texas Instruments

Agenda

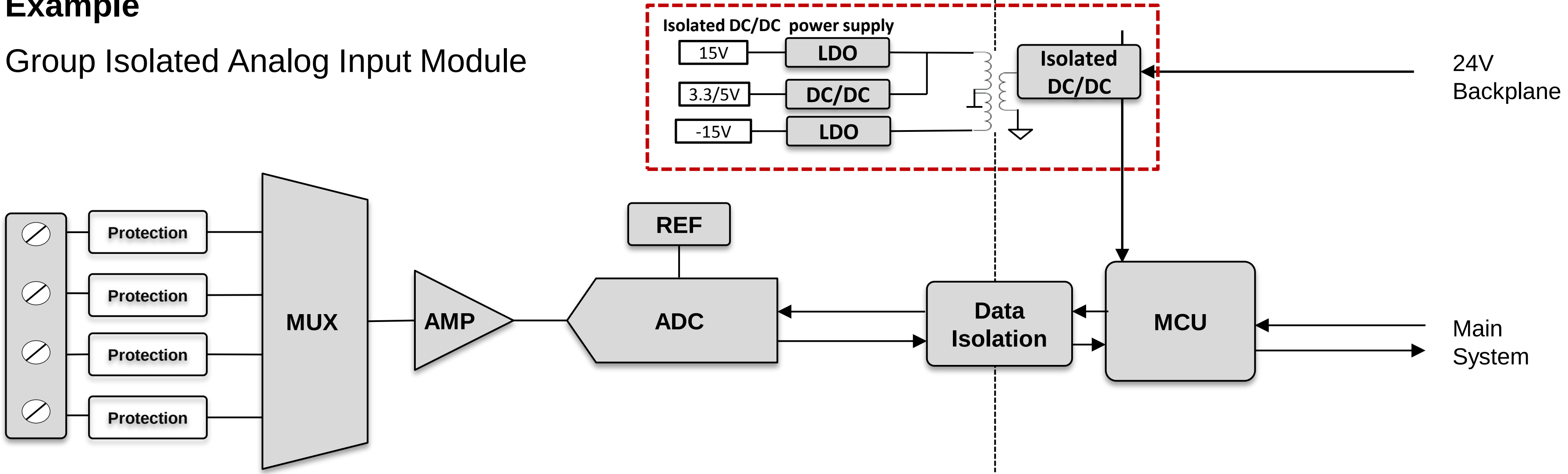
- Where and why?
- What are my choices?
- Fly-Buck - How does it work, what is important?
  - Working principle
  - Why duty cycles of 40-60% should be chosen
  - Effects of leakage inductance

Where and why?

- Where: PLC modules where only limited power is required (1-4 W)
- Why: Isolated supplies for Multiplexer, Amplifier, ADC, Reference, Isolator

Example

Group Isolated Analog Input Module



What are my choices?

- Push-Pull (SN650x)
  + Simple to use
  + Low cost
  - No regulation (especially critical for transformers with high turn ratios)

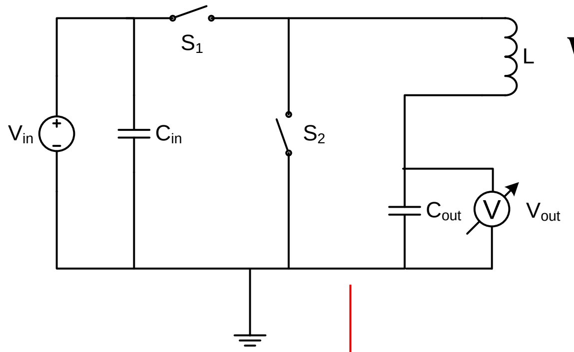
- Flyback (UCC28xxx)
  + Mid power (5W-100W)
  + Single primary switch
  + Wide V_{in} range
  + Good regulation (if secondary side regulated)
  - Needs optocoupler

- Fly-Buck (LM5xxx, TPS55010)
  + Low power (<10W)
  + Primary side regulation (no optocoupler)
  + Non-isolated + isolated outputs
  + Wide input range
  - Bad regulation

Active Clamp, Half & Full Bridge oversized for power requirements (mostly used for >50W)

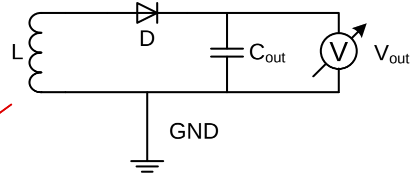
Fly-Buck – How does it work, what is important?

Topology

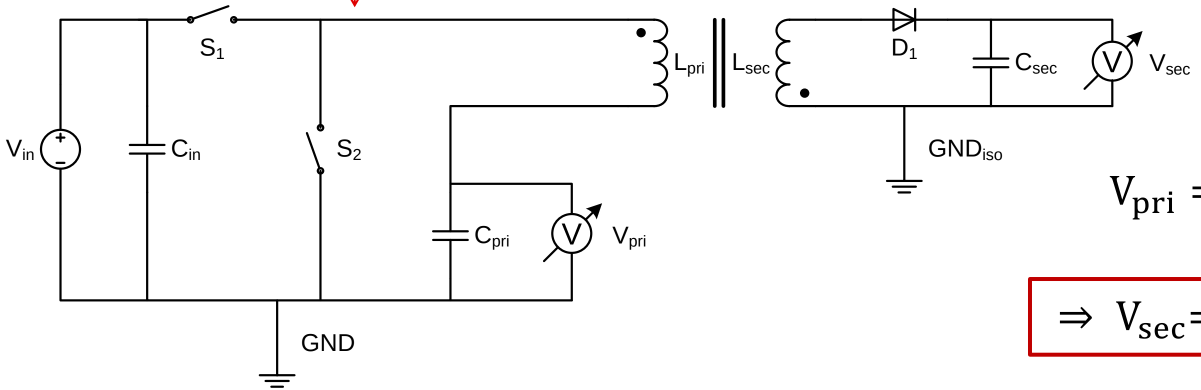


$$V_{out} = V_{in} \cdot D = Vin \cdot \frac{t_{on}}{t_{on} + t_{off}}$$

+



$$N = \frac{N_{sec}}{N_{pri}}$$

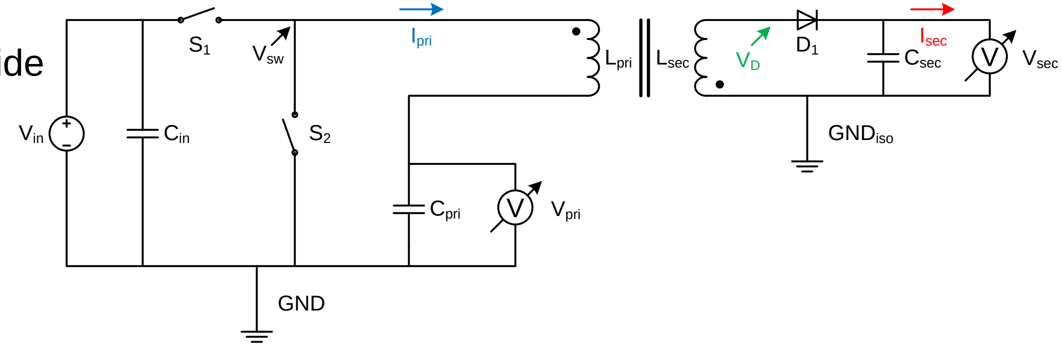


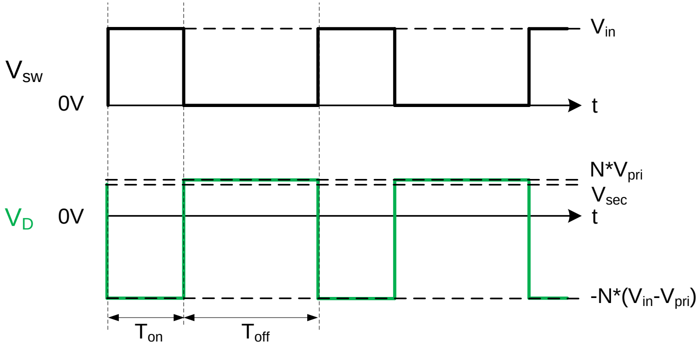
$$V_{pri} = V_{in} \cdot D = V_{in} \cdot \frac{t_{on}}{t_{on} + t_{off}}$$

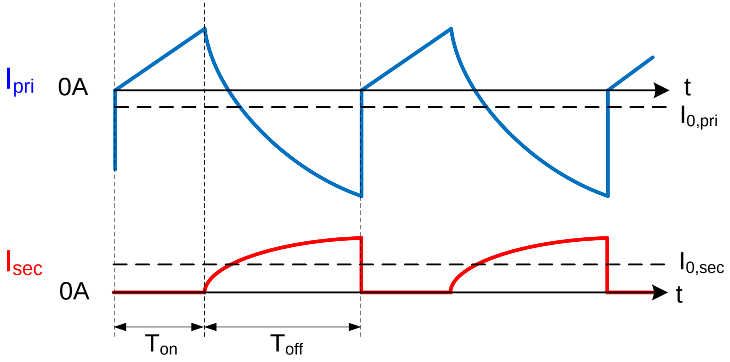
$$\Rightarrow \; V_{sec} = V_{pri} \cdot N - V_{D1}$$

Working Principle

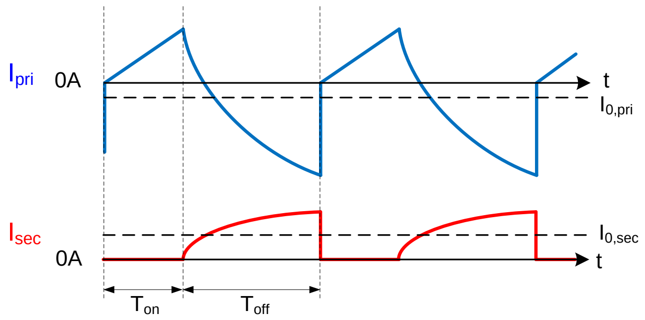
- t_{on} - S_1 closed, S_2 open:
  - Current flows through L_{pri}, secondary side voltage / D_1 is reversed biased
  - No current flowing
- t_{off} - S_1 open, S_2 closed:
  - Voltage across L_{pri} and L_{sec} reverses
  - Current flowing

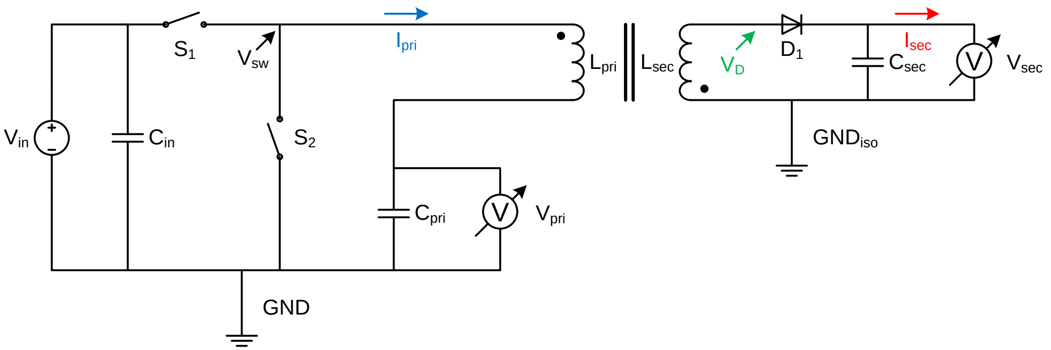






Why duty cycles of 40-60% should be chosen

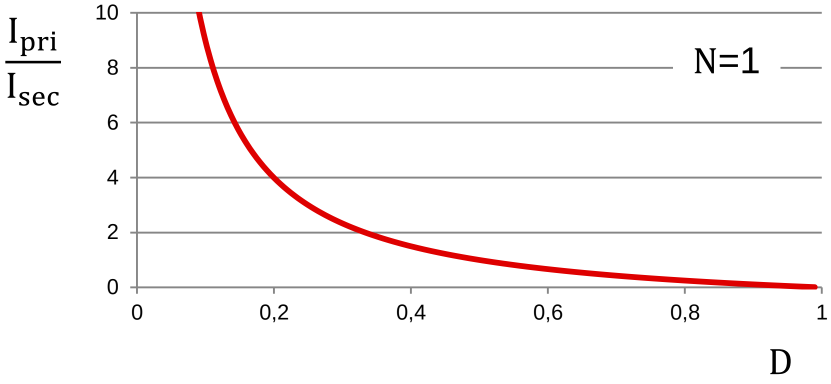




$$D = \frac{t_{on}}{t_{on} + t_{off}}$$

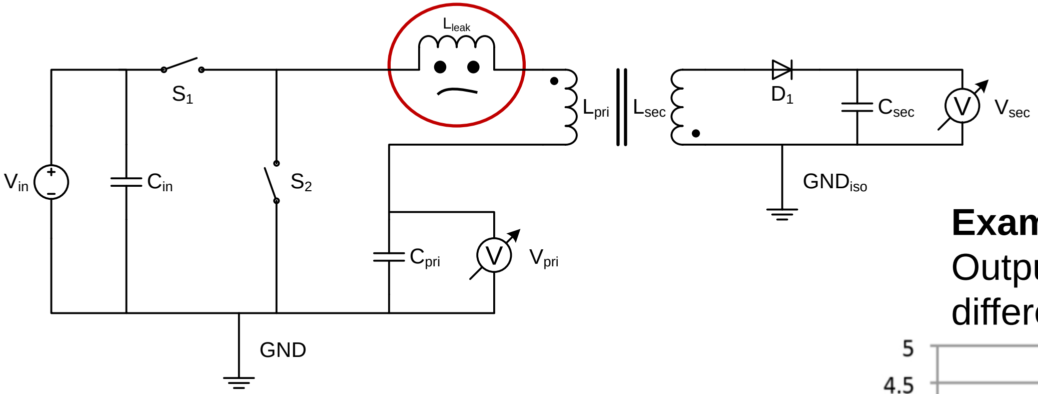
$$I_{pri} \cdot t_{on} = I_{sec} \cdot t_{off} \cdot N$$

$$I_{pri} = I_{sec} \cdot N \cdot \frac{1 - D}{D}$$



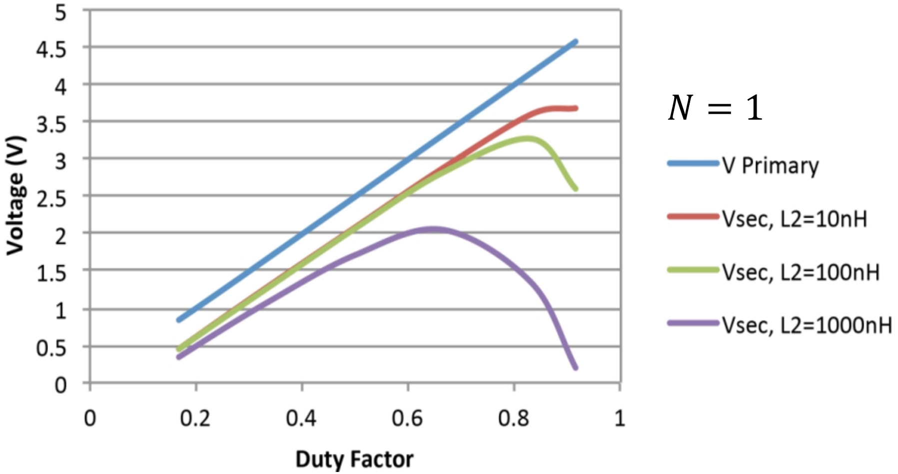
Too low or too high duty cycles lead to short energy charge or energy transfer times.
=> High peak currents on primary or secondary side
=> Transformer needs high saturation current rating

Effects of Leakage Inductance



- Lower leakage inductance
  - ⇒ Higher peak currents
  - ⇒ Higher voltage drop across D_1
- Higher leakage inductance
  - ⇒ High currents increase effect of already high leakage inductance
  - ⇒ Bad regulation

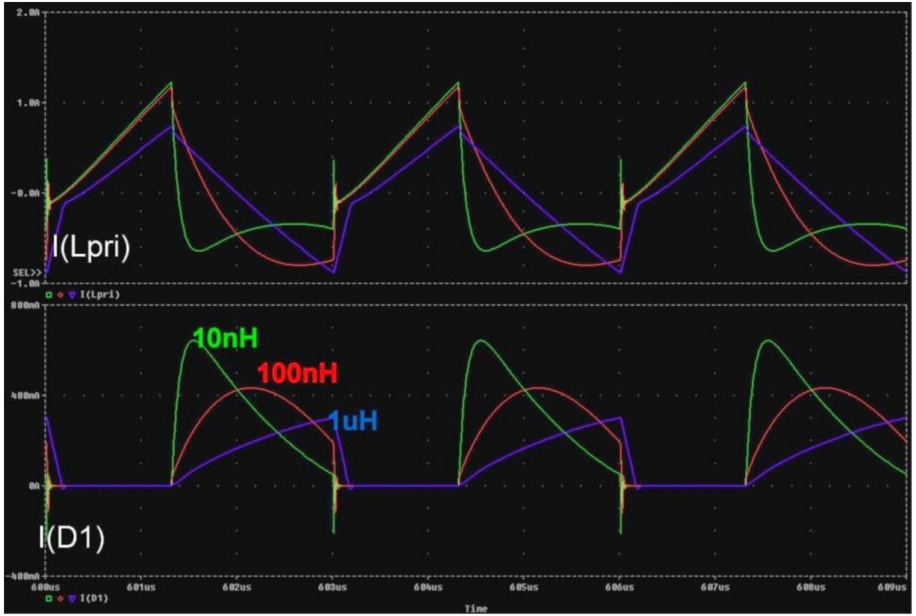
Example 1:
Output voltage over duty factor for different leakage inductance



Robert Kollman, http://www.eetimes.com/author.asp?section_id=183&doc_id=1321055

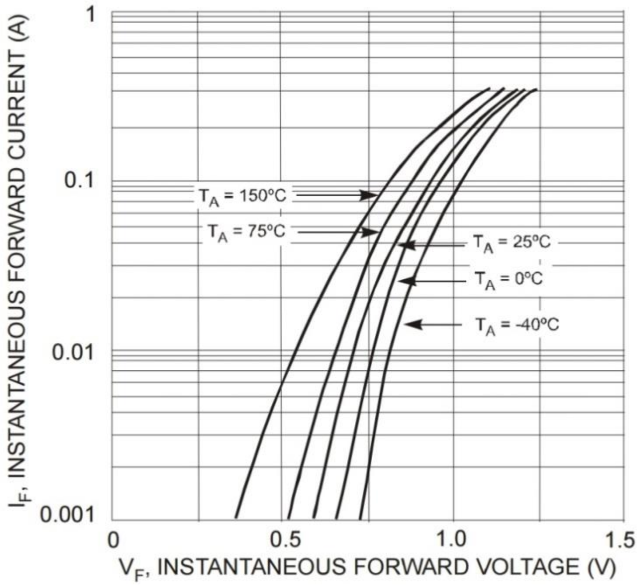
Effects of Leakage Inductance

Example 2:
Peak currents for increasing leakage inductance
⇒ High leakage inductance leads to “too slow” system



Robert Kollman, http://www.eetimes.com/author.asp?section_id=183&doc_id=1321055

Example 3:
Voltage drop across diode for increasing forward current



http://www.diodes.com/_files/datasheets/ds30086.pdf , Fig. 2

Resources

LM5017 Fly-Buck: Top Industrial Applications

Factory Automation
PLCs and Motor Drives

- **Bias power from main bus**
- **+/- bias voltage rails**
- **Analog/digital I/O isolation**

TIDesigns

- **PMP7993.1:** ±5V & ±15V outputs
- **PMP10535.1:** ±5V & ±12V, low profile
- **TIDA-00174:** IGBT driver bias for AC motor drive

Smart Grid
E-meters & Solar Inverters

- **Bias power for RS485**
- **Bias power for PLC/Relay**
- **Inverter system bias supply**

TIDesigns

- **PMP9461:** Microinverter Gate Drive and System Bias
- **PMP9310:** Non-isolated offline power supply for E-meter

Other Industrial
Power Supplies & E-bikes

- **Power Modules: Digital PWM controller bias (UCD3k)**
- **eBikes: system bias supply**

TIDesigns

- **PMP4394:** 1W isolated SIP module
- **PMP8581:** 48Vin, synchronous buck power supply in TO-220 footprint

Further TI Designs

- **Ultra-Small 1W, 12V-36V Iso Power Supply for Analog Prog Logic Controller Modules Reference Design (TIDA-00237)**
- **1W Isolated Power Supply with Planar Transformer Reference Design (TIDA-00688)**
- **Small Footprint Isolated Analog DC/DC Converter Reference Design (TIDA-00689)**

LM5160A Fly-Buck Application-based TI Designs

Industrial PLCs

Application Needs
- 24V input bus typical
- 18-32V Vin range
- Isolated multiple outputs
- Up to 15W total output

Reference Design
- Isolated triple output 5V@1A, +/-15V@200mA

PMP10532

Industrial AC Motor Drive IGBT Bias

Application Needs
- 24V input bus typical
- 18-32V Vin range
- Isolated multiple outputs
- Up to 15W total output

Reference Design
- Isolated 8 outputs 15V/-8V@150mA for

PMP10531

EV/HEV Bias

Application Needs
- 12V battery, 6-16Vin range
- Isolated single or multiple outputs
- Up to 6W total output

Reference Design
- 3 designs: Isolated +15V@150mA, -9V/150mA, and 5V/200mA for CAN bus

PMP10588

POE Powered IP Camera/IP Phone

Application Needs
- 48Vin typical
- 36-57V Vin range
- Isolated or non isolated 12V or 5V output
- Up to 12W output power

Reference Design
- 12W POE solution LM5160+TPS2378

PMP10572

www.ti.com/automation

www.ti.com/flybuck