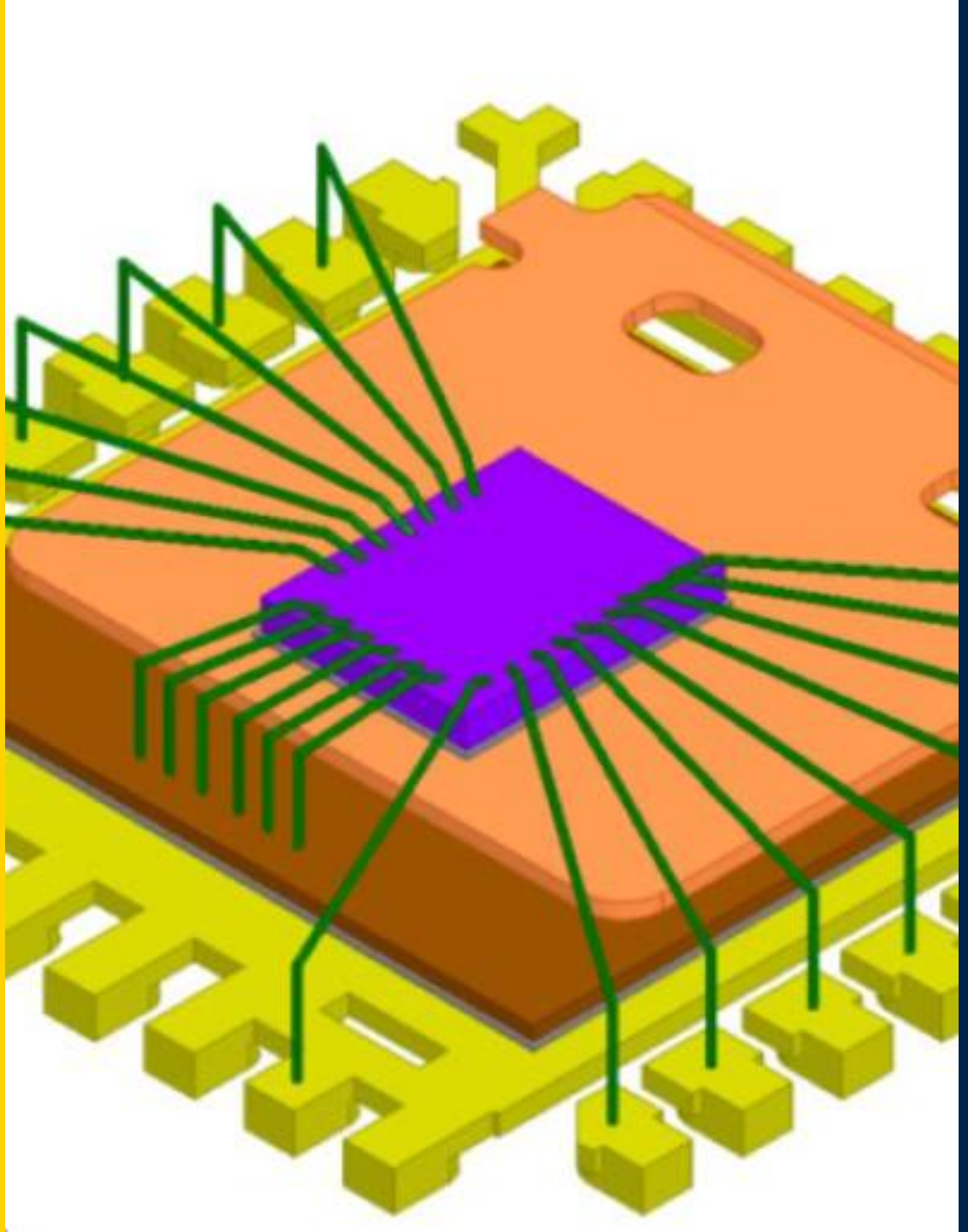

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Electronic fuses – modern way of system protection. IC design perspective

Petényi Sándor

28-Nov-2025

Agenda

- Introduction
- Architecture
- Mechanical construction
- Parameters and features
- Precise current sensing
- eFuse products
- Conclusion
- Discussion

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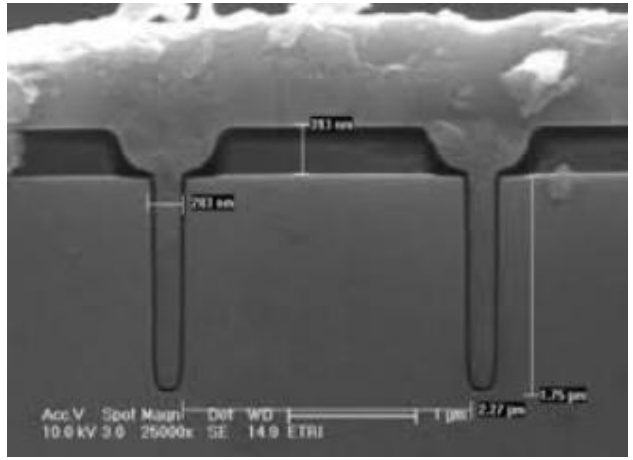
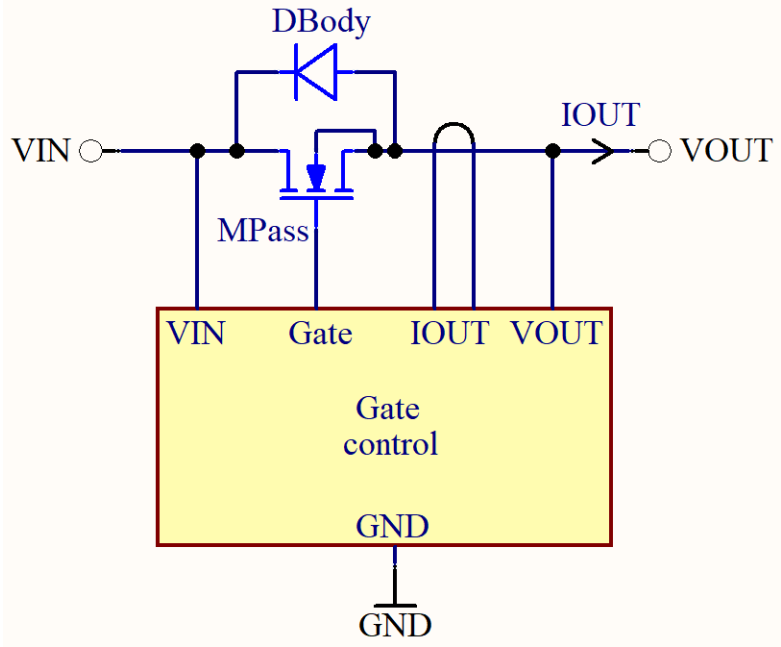
Introduction





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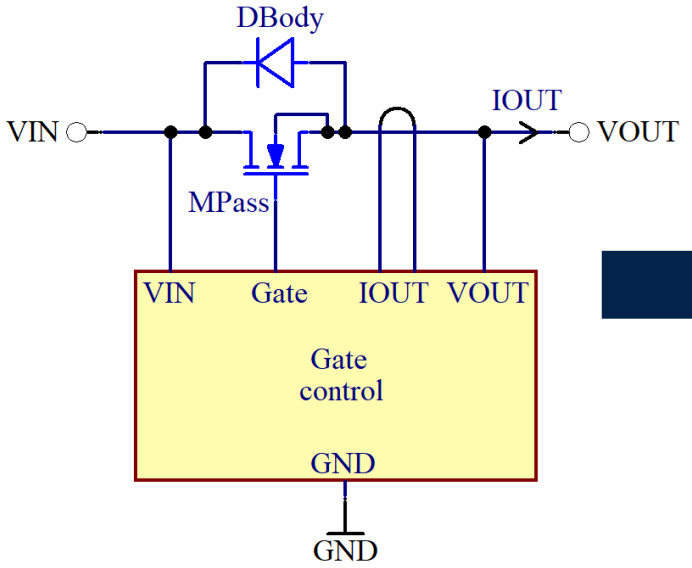
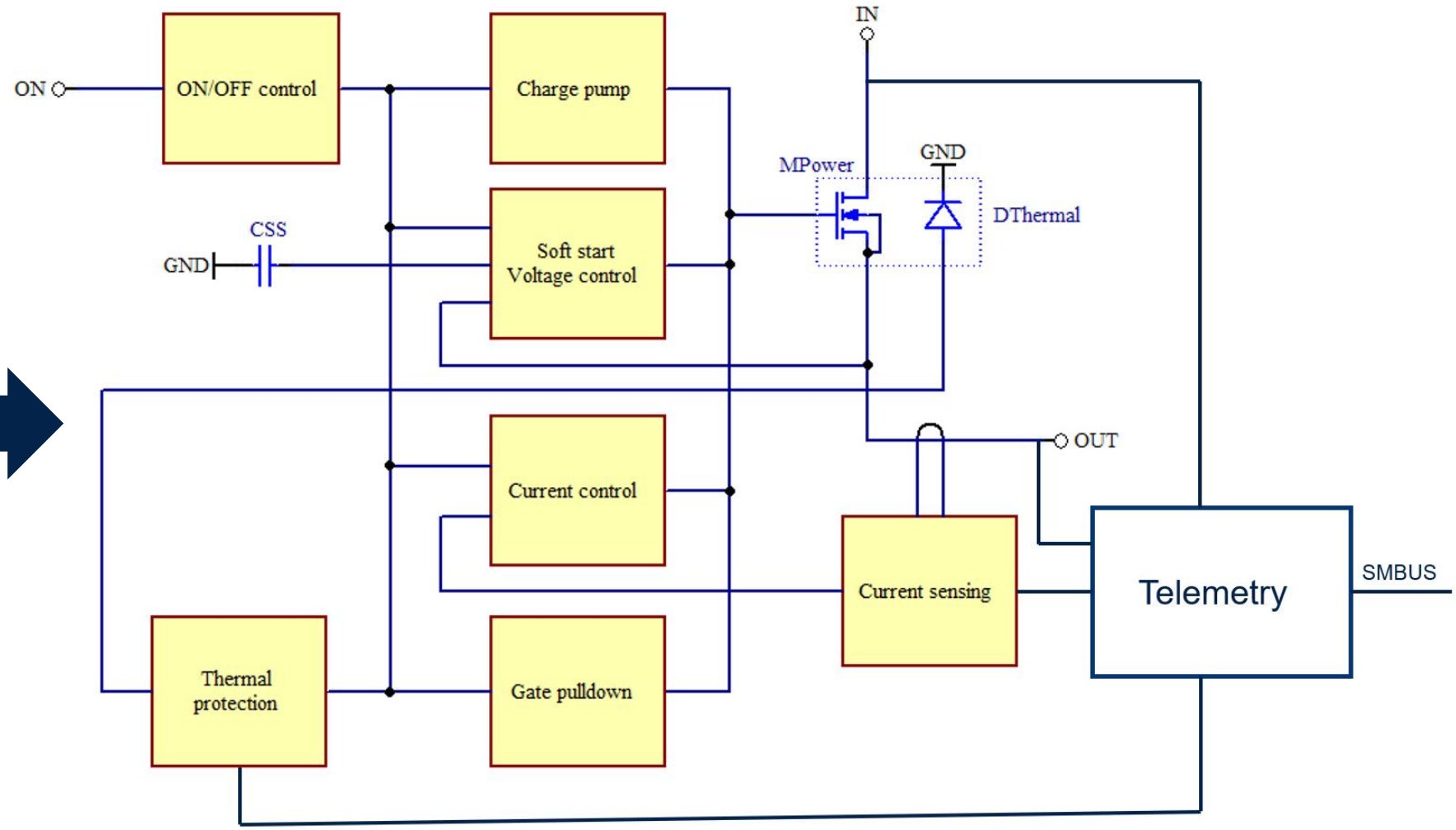
Architecture

- Power pass element - MOSFET
  - Not self-protected
  - Very strong inside specified operating range
  - Fragile outside specified operating range
  - Operating range limited by V_{GS}, V_{DS}, I_D, SOA, Z_{TJA}, T_{MAX}
- Controller
  - Keeping always the MOSFET in safe condition
  - It must detect and protect
    - System
    - Power path of the eFuse

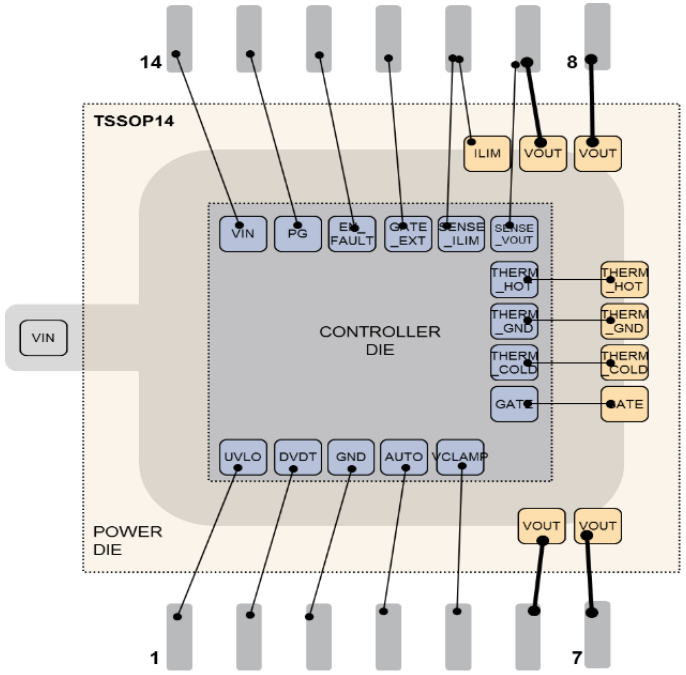
Architecture



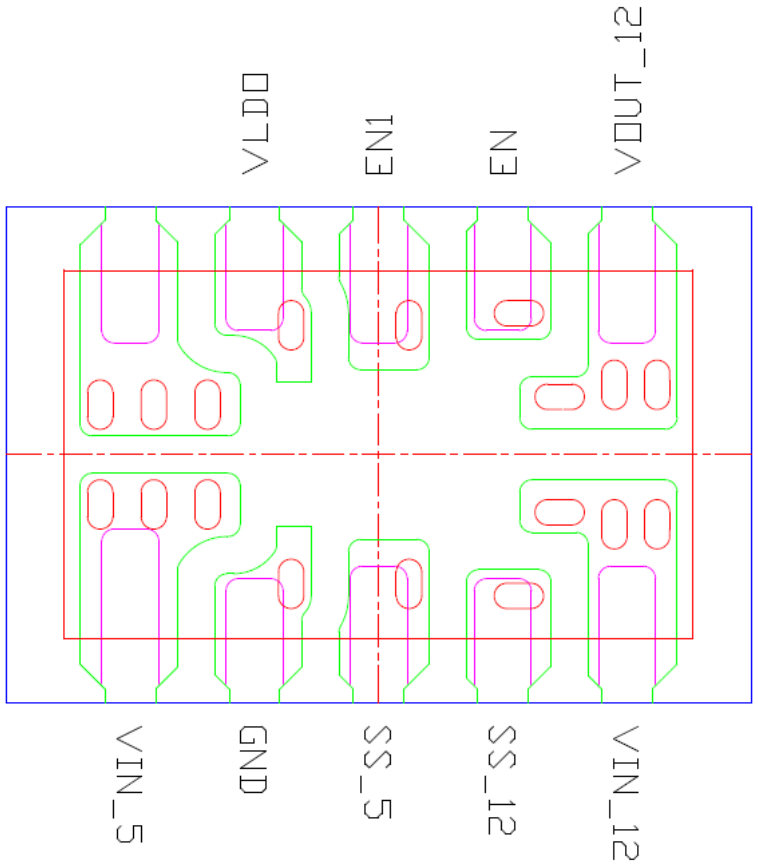


Mechanical design

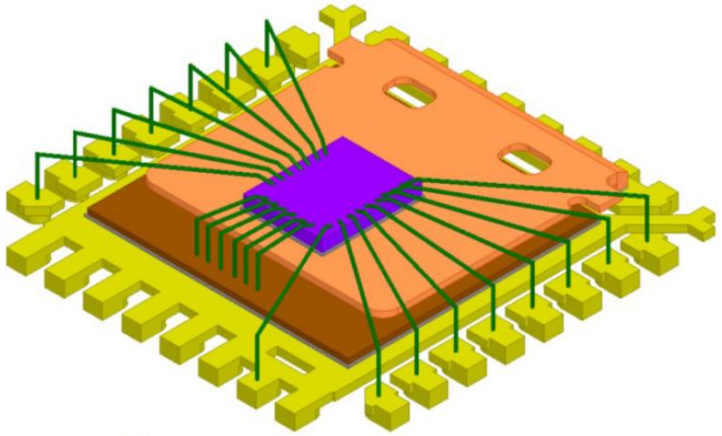
STEF01/24

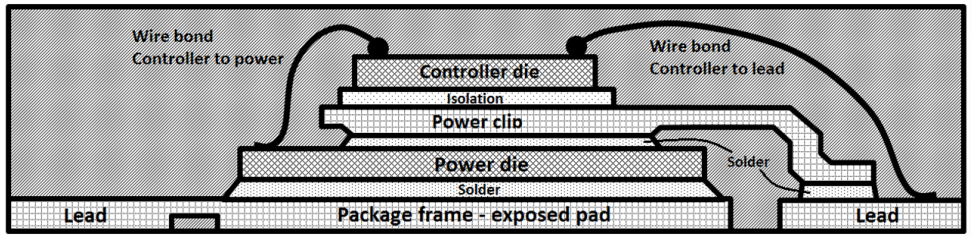


STEF512SR(X)



STEF12H60



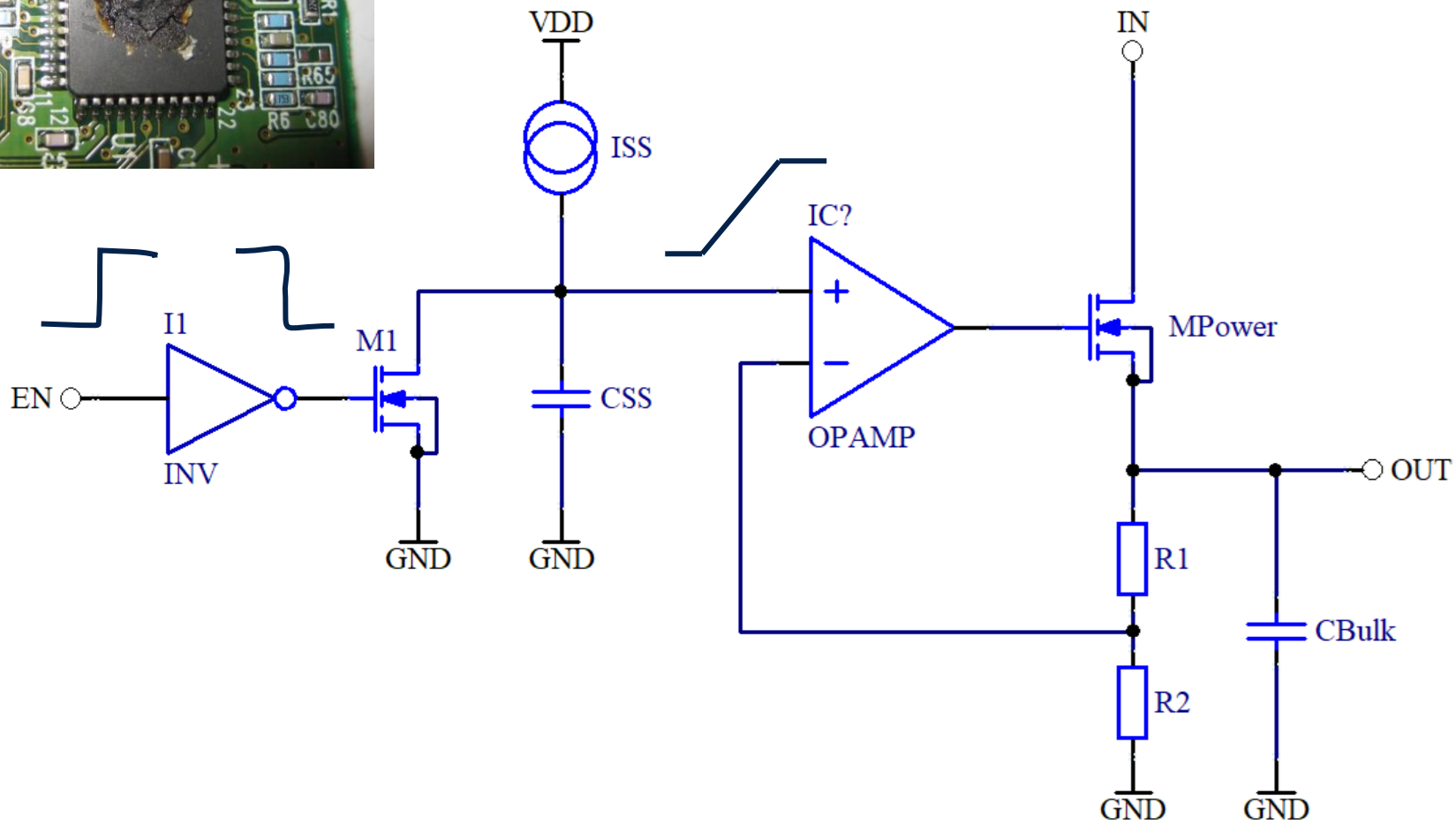


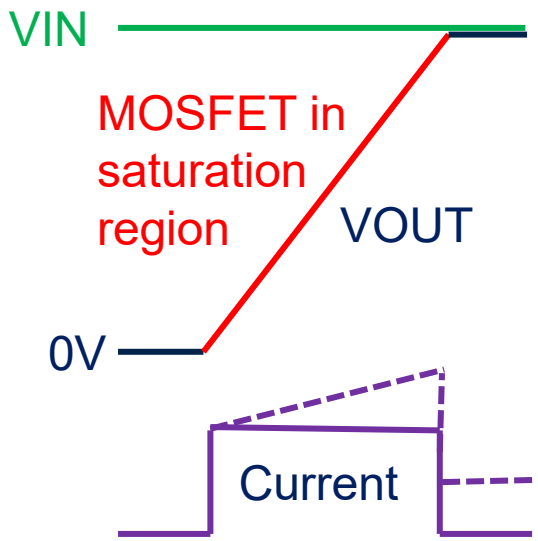
Critical parameter

- Safety
- RDSON – sub mΩ range
- Maximum VIN – at least 2x the operating voltage
- Maximum ILOAD
- Power MOSFET SOA
- Precision of current sensing – single % range
- Ruggedness – no latch-up, accept negative voltage on VOUT

Features

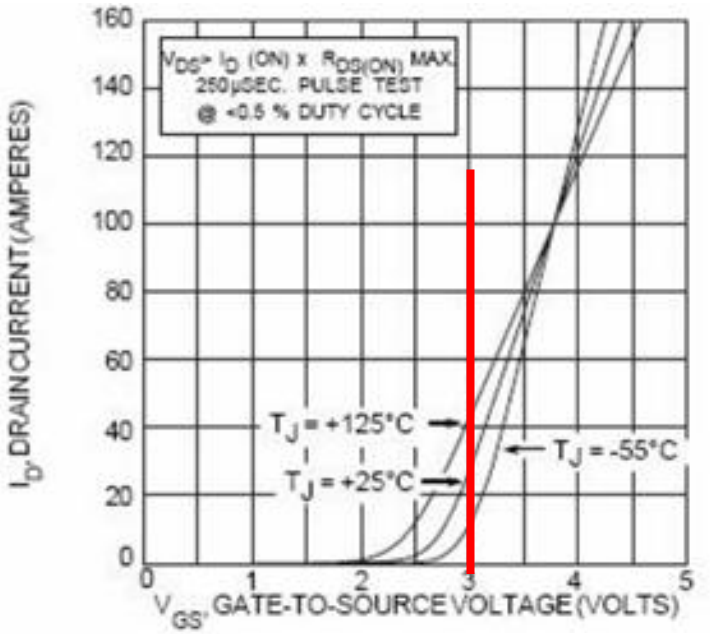
Startup

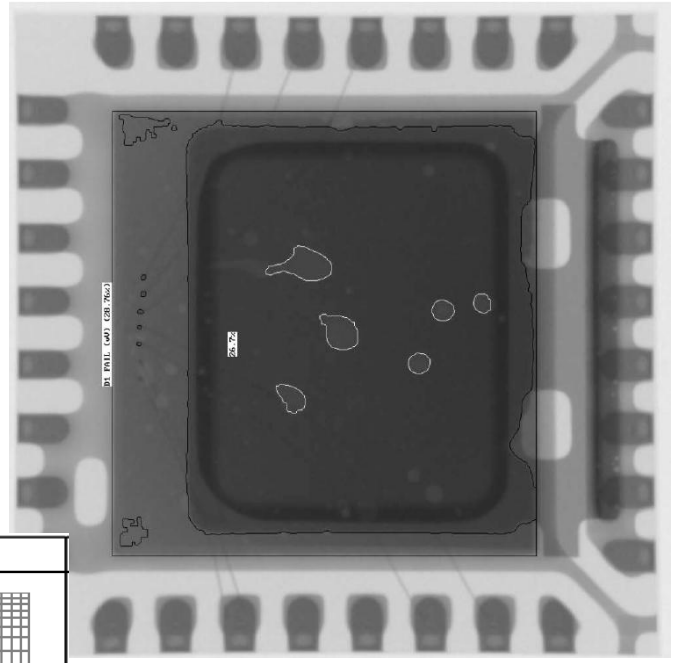




Features

MOSFET SOA





Voids

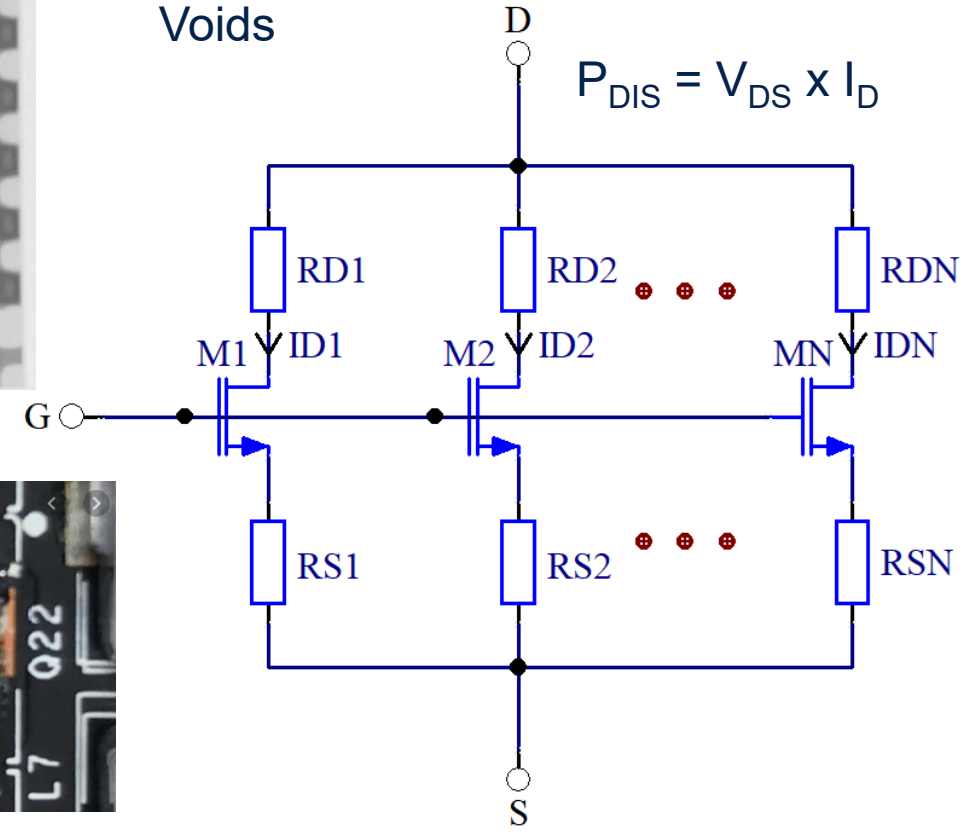
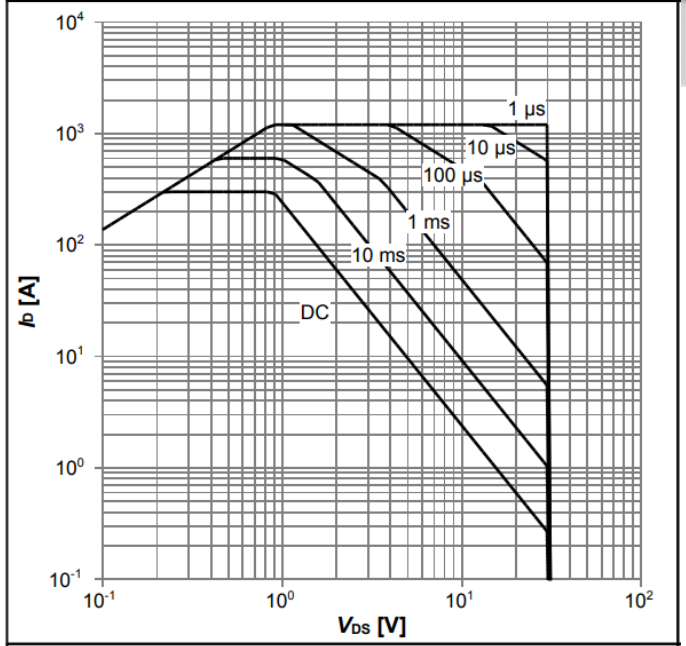
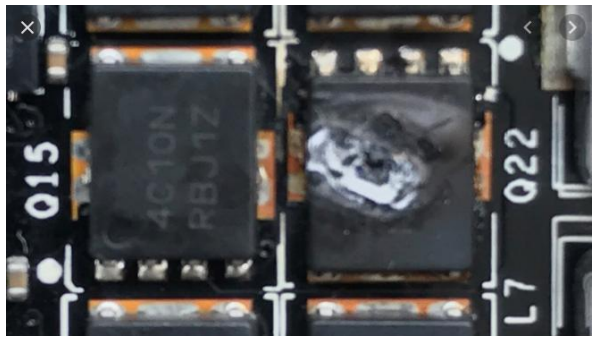


Diagram 3: Safe operating area



I_D=f(V_{DS}); T_C=25 °C



- Big problem for high voltage MOSFETs

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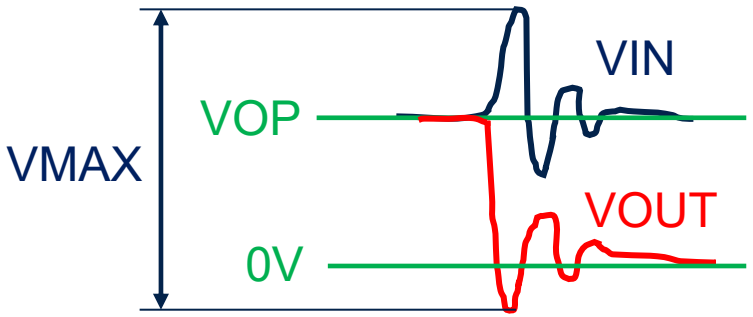
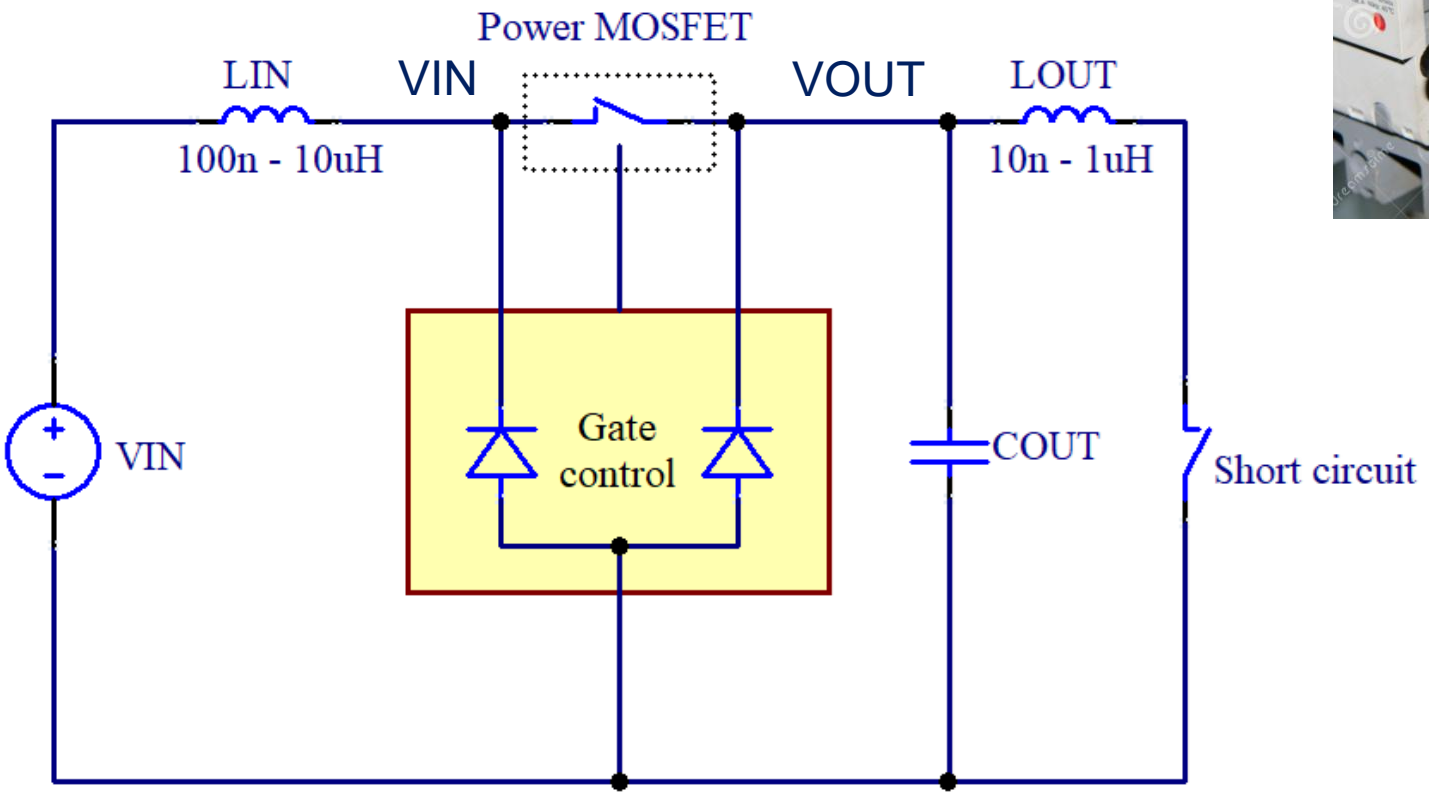
Features

Line transients and power path disconnection



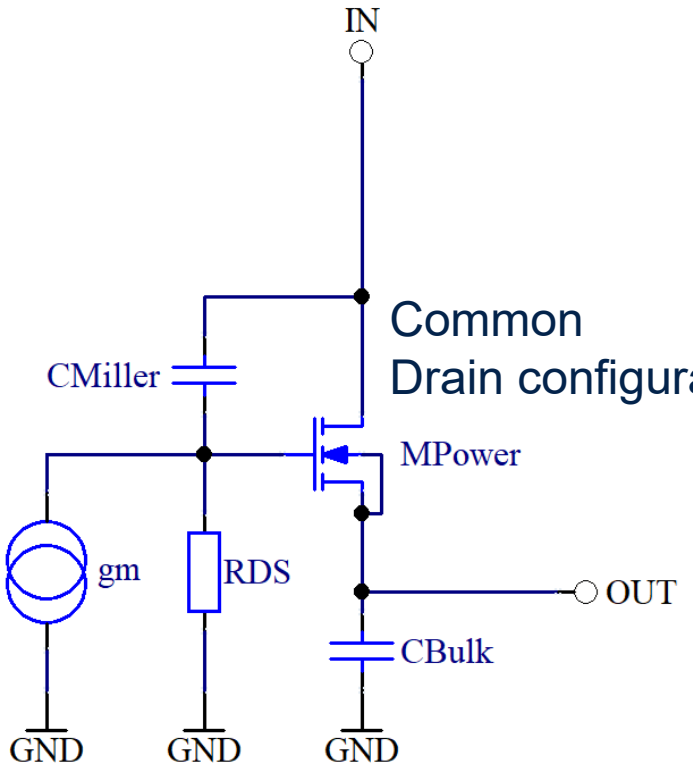


Features

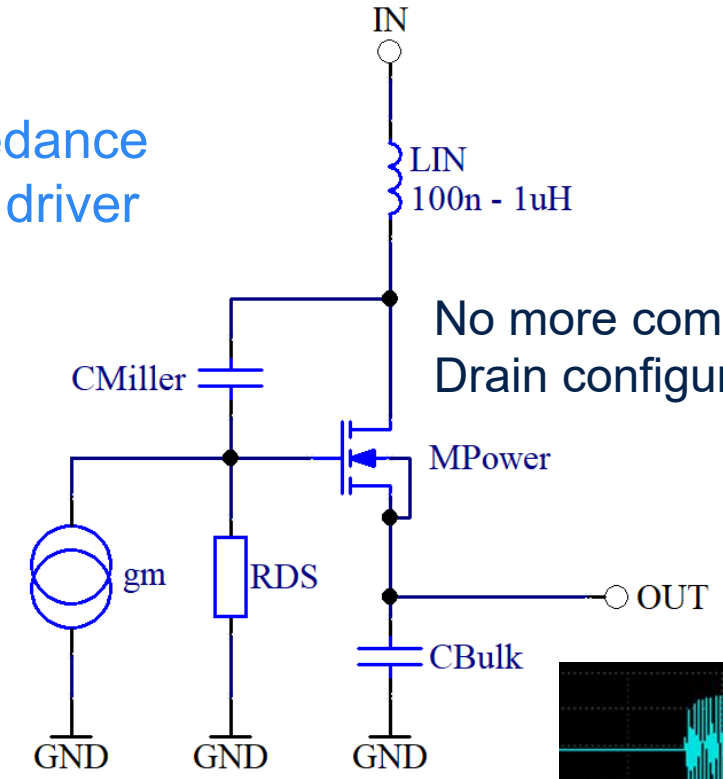
Loop stability

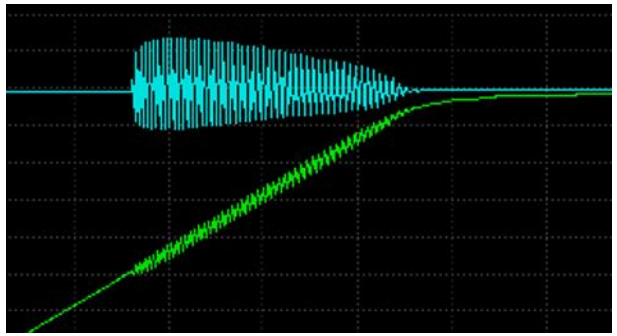
- Avoiding feedback amplifier wherever possible
- Gain as low as possible
- Low impedance gate driver
- Specifying LIN range
- Bandwidth lower than resonant frequency
- Using threshold detection + timing instead of loop regulation

Amplifier



Oscillator





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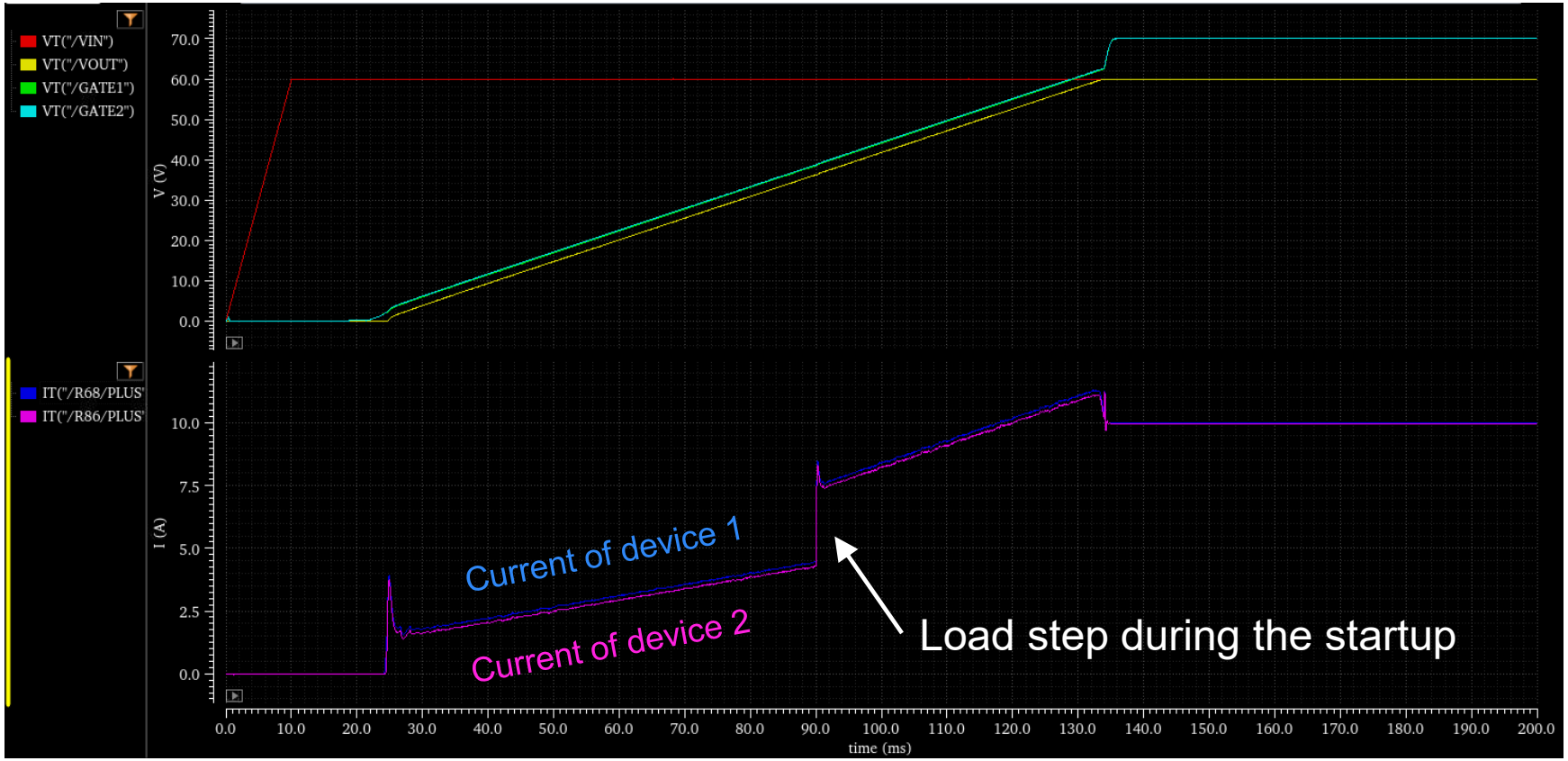
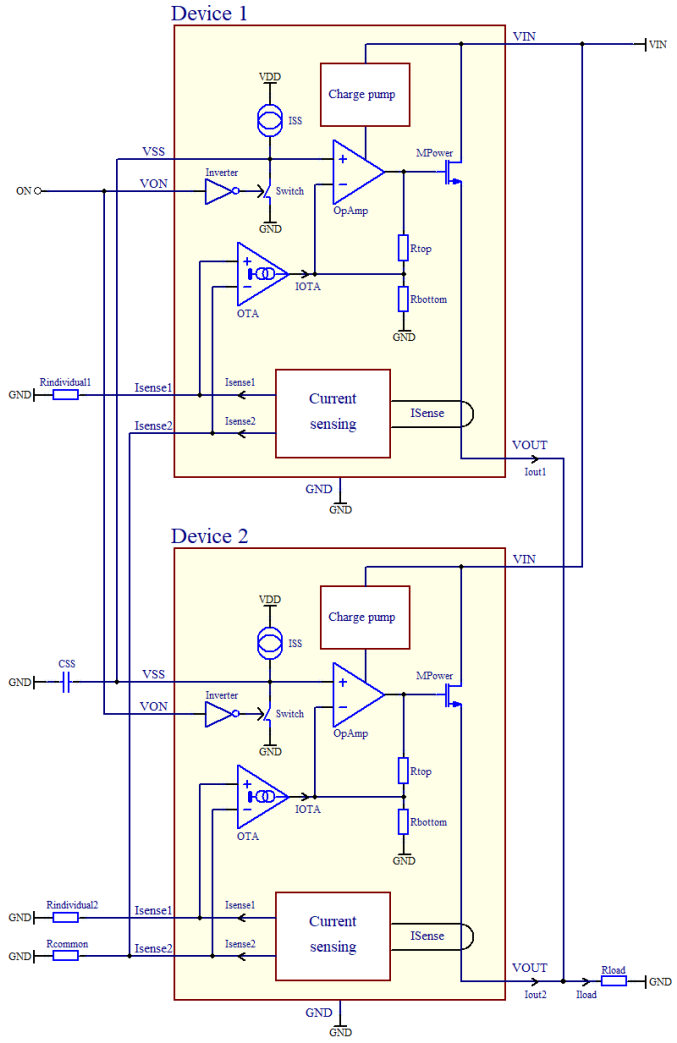
Features

Parallel operation – current sharing during startup

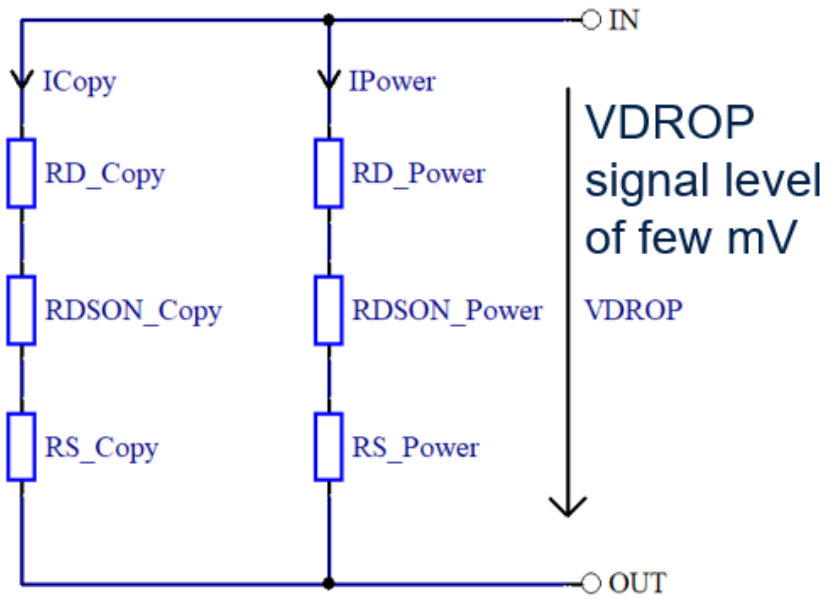




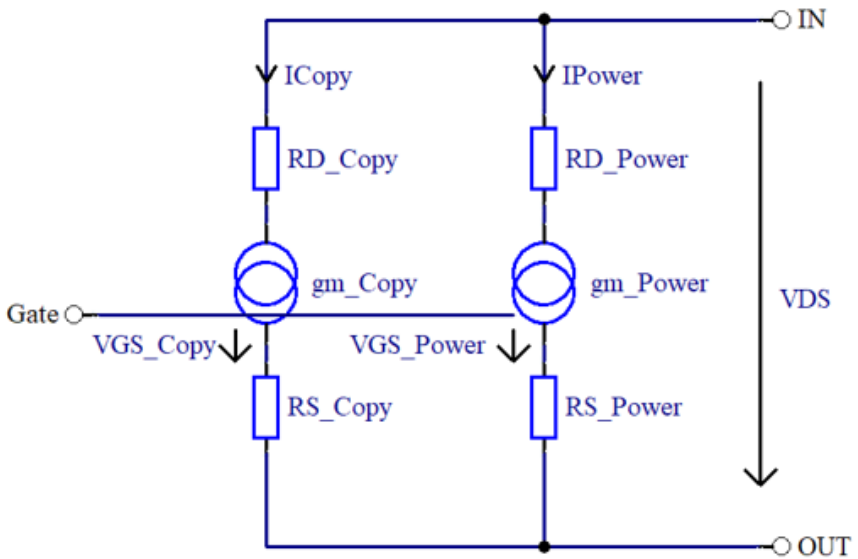
Patent pending. Application number 18139786.

Precise current sensing

Linear mode



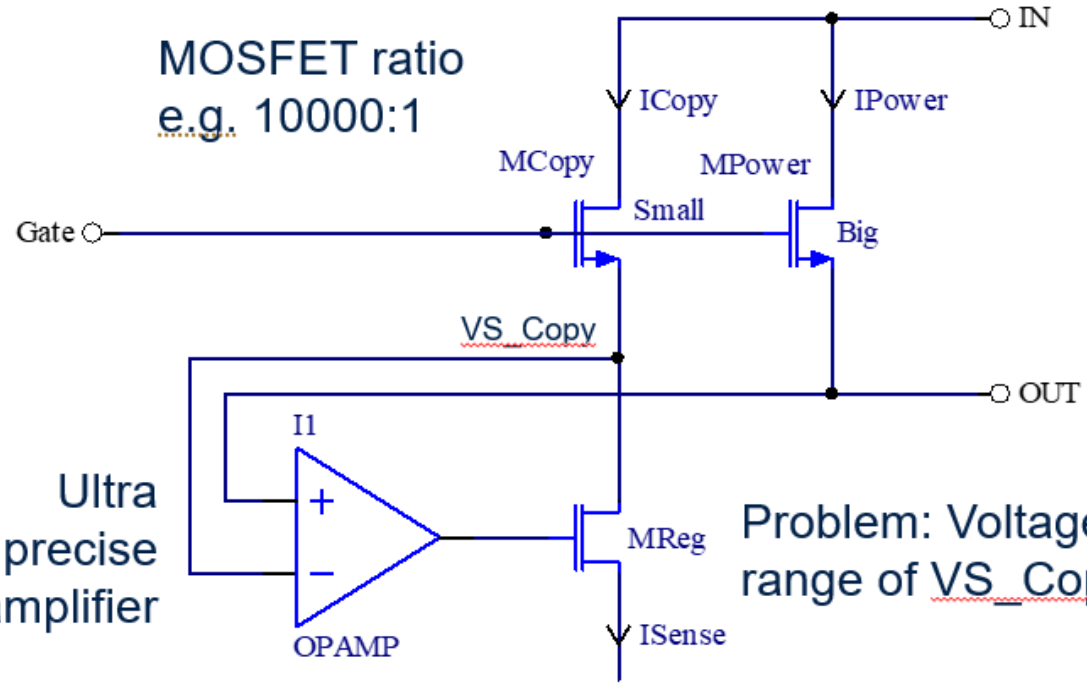
Saturation mode



Current sensing 1/2

Are the MOSFETs really matched?

MOSFET ratio
e.g. 10000:1



Ultra precise amplifier

Problem: Voltage range of VS_Copy

Precision expectation +/-2%
Sensitive on different parasitic effects, e.g. mech. pressure

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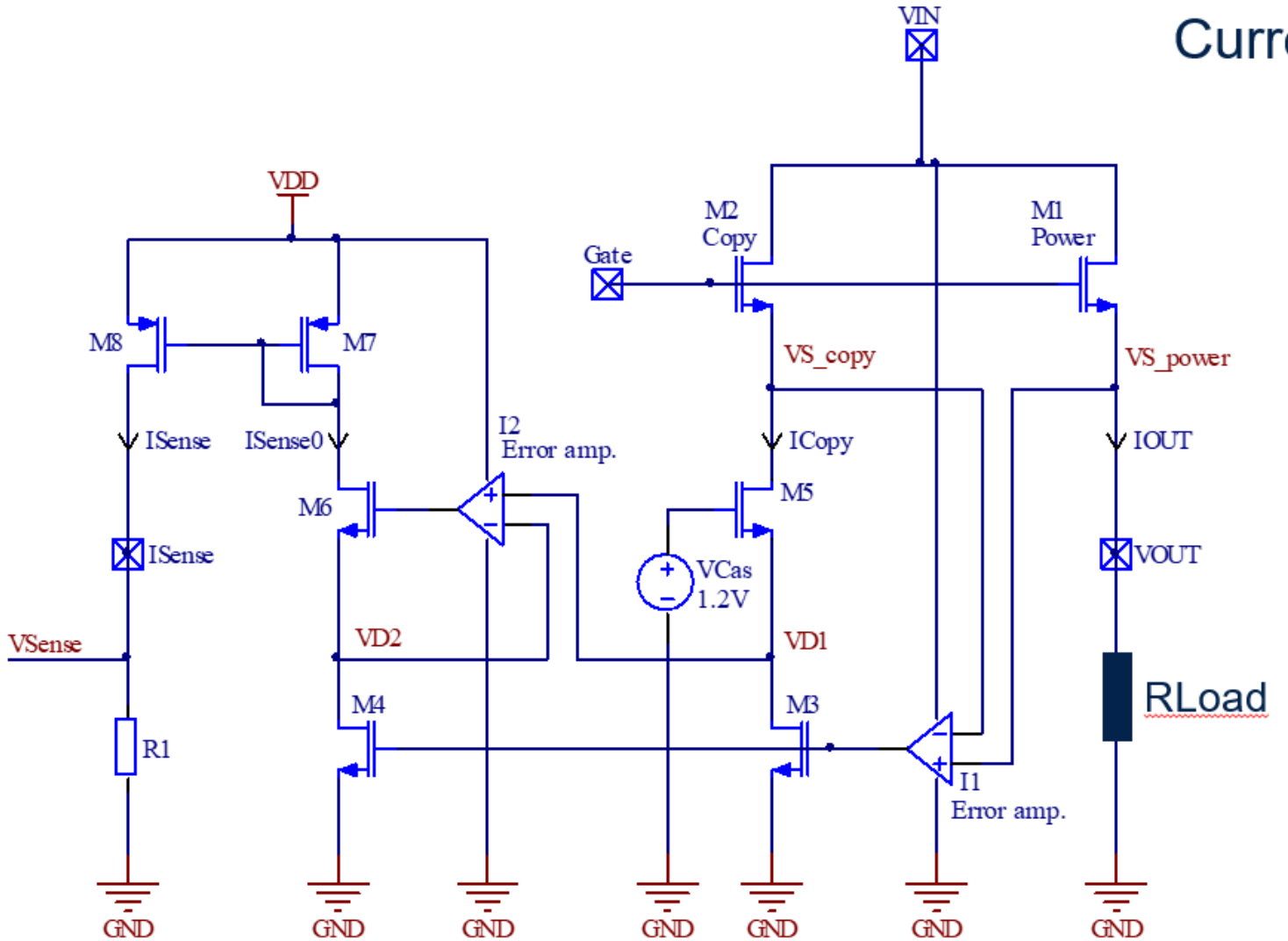
Precise current sensing

Current sensing 2/2



Patent: 10295577 - Current sensor with extended voltage range

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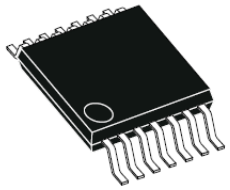
eFuses designed in Prague

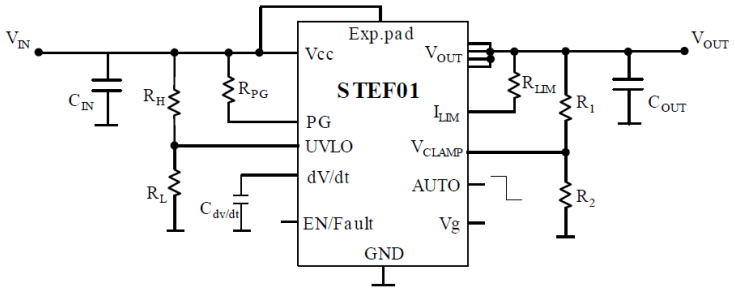
STEF01/24



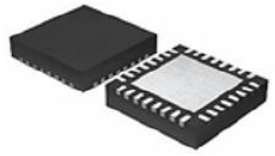
HTSSOP14

Features

- Operating input voltage range: 8 to 48 V
- Absolute maximum input voltage: 55 V
- Continuous current typ.: 4 A
- N-channel on-resistance typ.: 30 mΩ
- Enable/fault functions
- Output clamp voltage: adjustable from 10 to 52 V



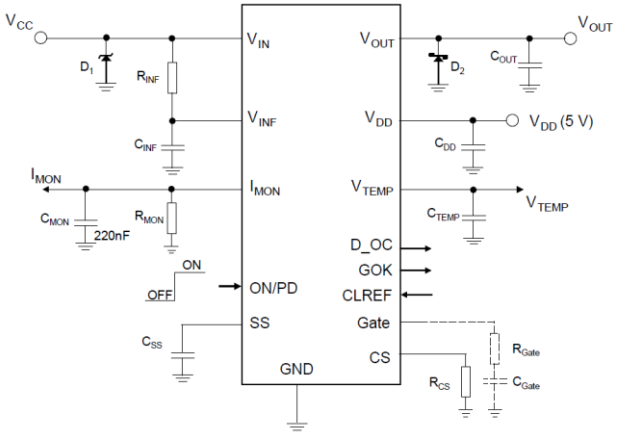
STEF12H60/M/G



QFN 32 (5 x 5)

Features

- 60 A continuous current
- Input voltage range from 5 to 18 V
- Adjustable current limit
- Input undervoltage lockout
- Integrated 0.85 mΩ Power MOSFET
- Enable/Disable pin
- Programmable turn-on time
- Accurate current monitor signal
- Precise temperature monitor
- Overcurrent and Fault status flags
- Internal MOSFET self-diagnostic
- Parallel operation



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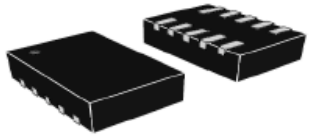
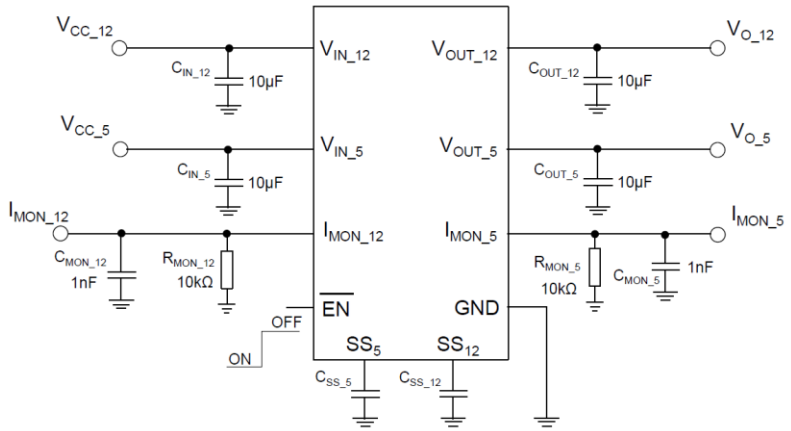


DFN10-2x3

Features

- 5V and 12V channels into one chip
- 25V Absolute Maximum Input Voltage
- Precise Output Over Voltage Clamp
- Fixed overcurrent protection trip point
  - 3A, 3.3A on 5V, 4A or 4.5A on 12V
- Reverse current protection on 5V channel
- Thermal Protection
- Available in Thermal Latch (or Auto re-try on request).
- Input Under Voltage Lockout
- Adjustable Output Voltage Slew Rate for each channel by external C_{SS_x} capacitors
- Integrated 40mΩ Power MOSFETs



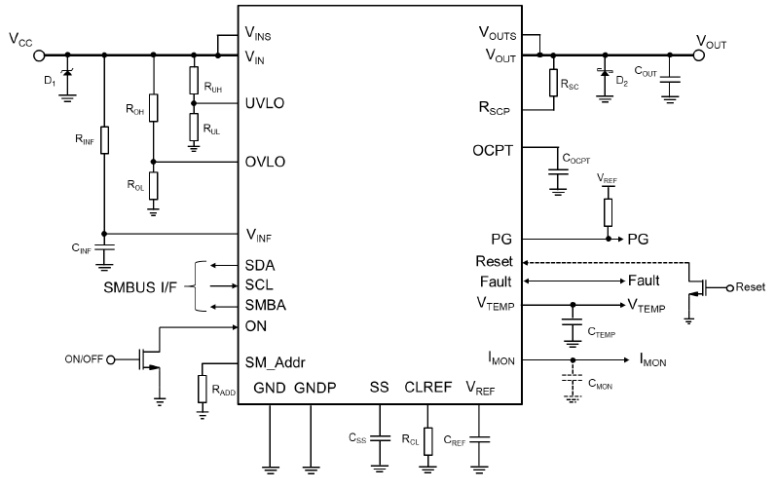
eFuses designed in Prague

STEF48H28/30

QFN42L – (7x7 mm)

Features

- 30 A continuous current
- Input voltage range from 9 to 80 V
- Absolute maximum rating 95 V
- SMBUS™ interface
- PMBUS®™ V 1.3.1 commands compliant
- Adjustable UVLO and OVLO
- Integrated 1.7 mΩ power MOSFET
- Overcurrent protection with adjustable threshold and timeou
- Fast, adjustable short-circuit protection
- Thermal protection
- Power good, fault, and reset functions
- Programmable soft-start and turn-on delay time
- Precise current monitor signal
- Precise temperature monitor
- Digital voltage, current, power, energy, and temperature telemetry
- Parallel operation
- Integrated MOSFET diagnostic features
- Integrated black-box function
- Fault latch or auto-retry configuration
- -40 °C < T_J < 125 °C operating temperature
- QFN42L (7x7 mm) package - IPC2221B 100 V spacing compatible



Future

800V fuse?

Conclusion

- eFuse – is a smart way of system protection and hot swapping
- The controller circuit must be very robust, handling extreme situations
- The power MOSFET must have sufficient margins in SOA and VDS
- Precise current sensing is a challenge

Thank you

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