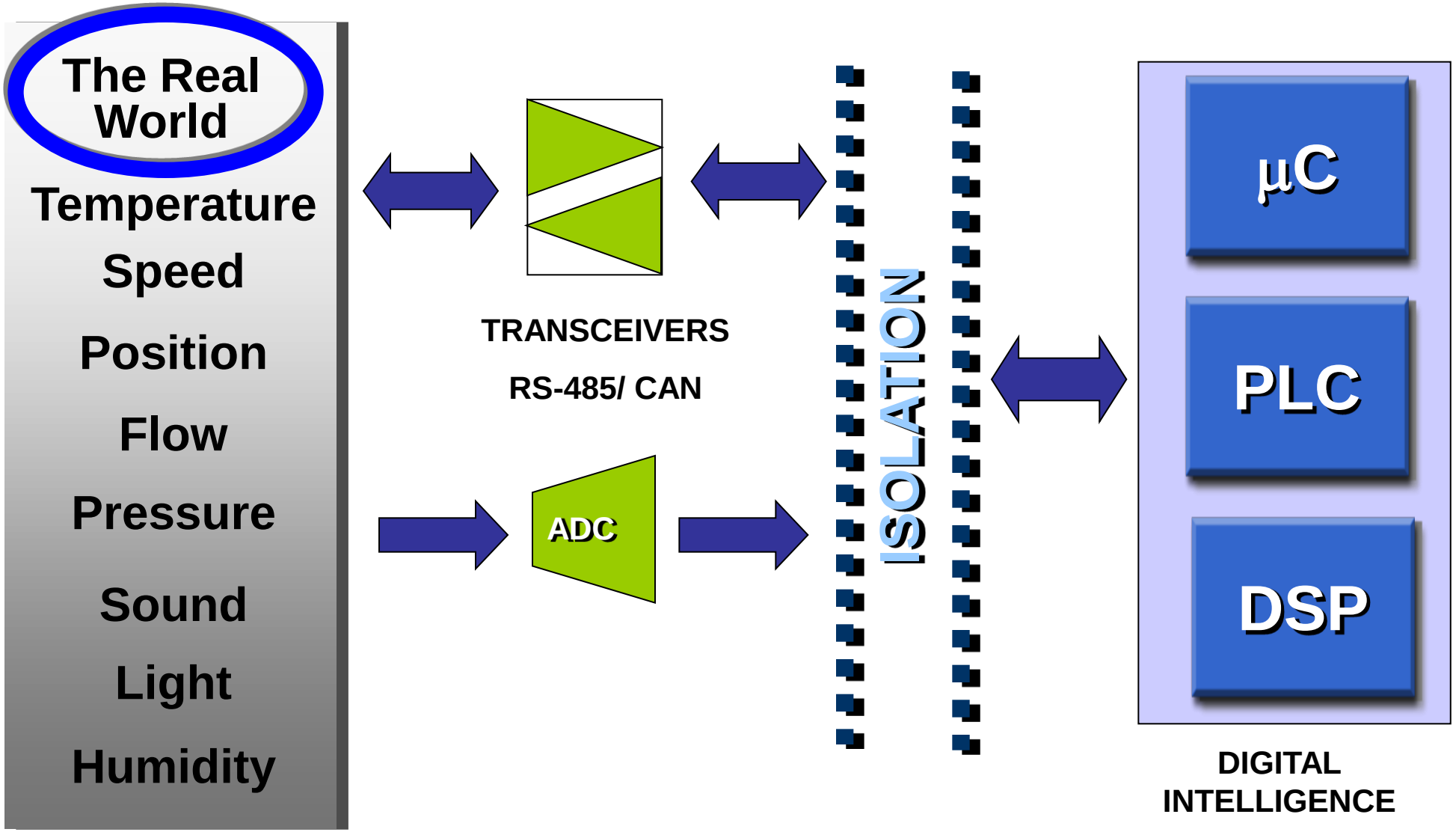
TI Technology Days 2010

Capacitive Isolation

Frank Dehmelt

Signal Isolation



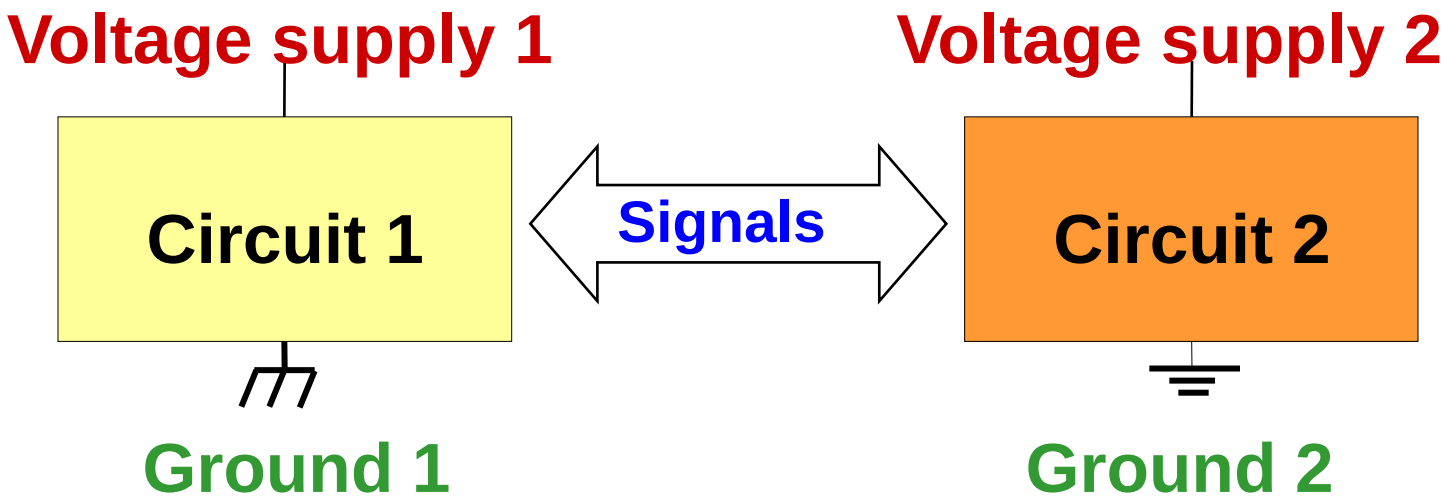
What is Isolation?

Galvanic isolation:

Although Circuit 1 and Circuit 2 exchange signals, no current (electrons) pass from Circuit 1 to Circuit 2.

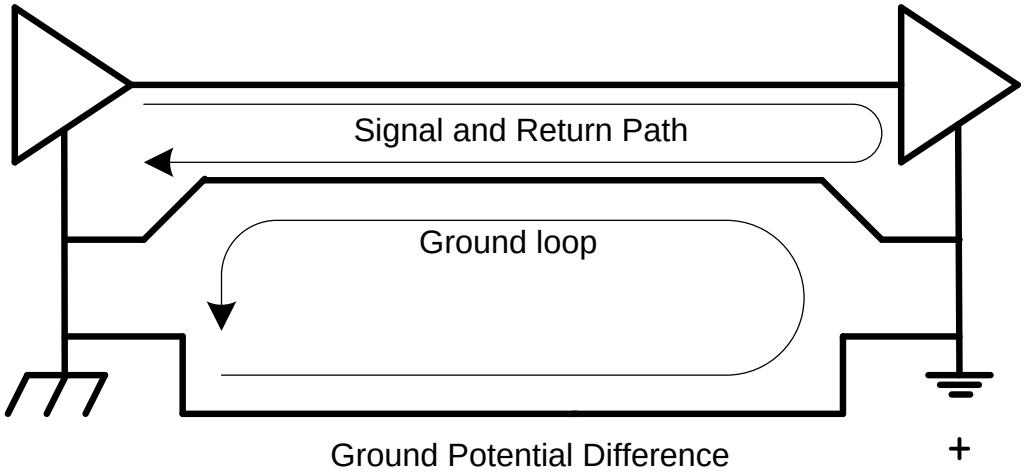
Why is isolation required in electrical systems:

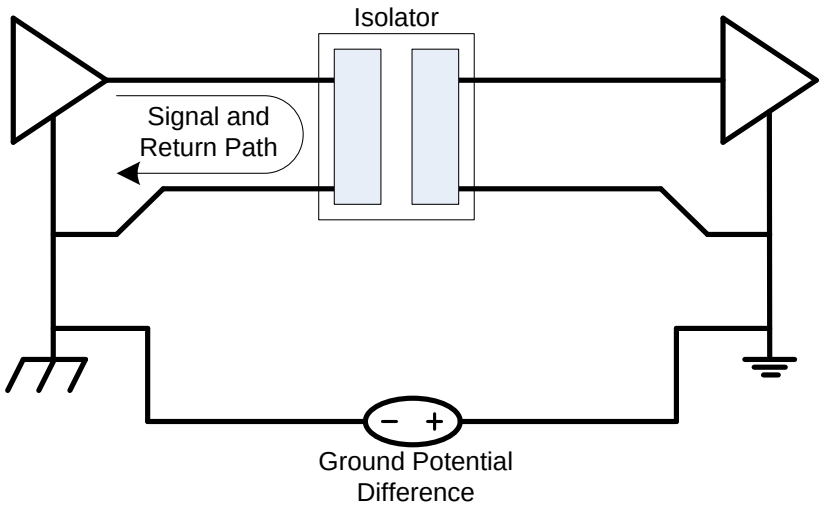
- **Break ground loops**
- **Reduce common mode noise**
- **Safety from high voltages**



Why Isolation?
Ground Loops

- More than one conductive path between two circuits creates a ground-loop
- Multiple ground paths may lead to unintended equalization currents

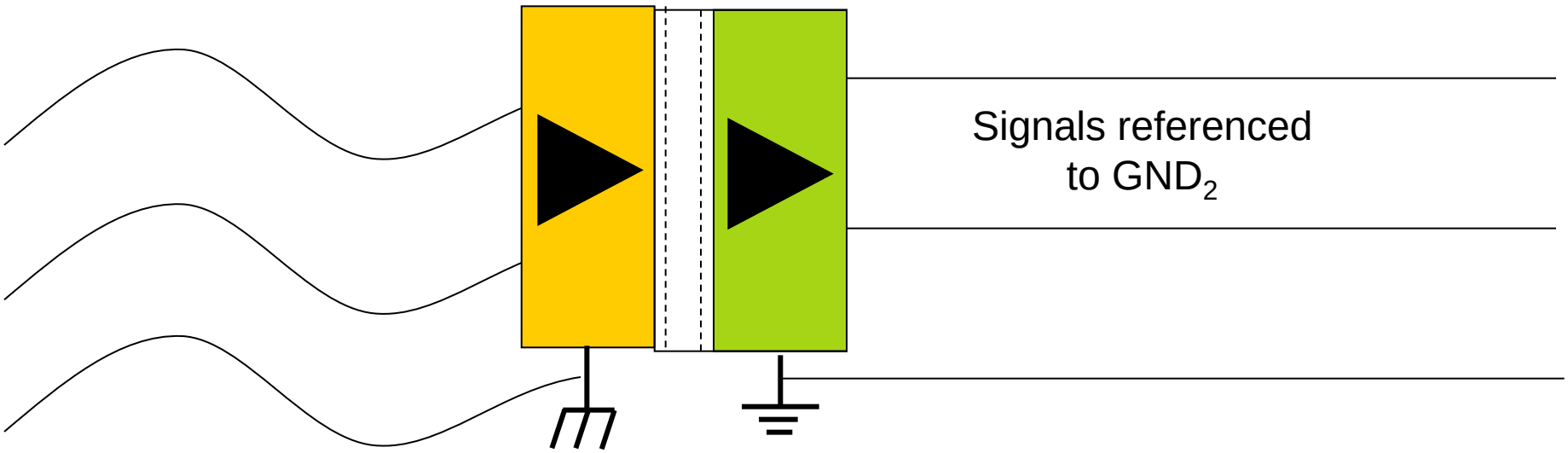




Ground loop can be broken by
- Disconnecting the grounds
- Common-mode chokes
- Frequency selective grounding
- Differential amplifiers
- Galvanic isolators

- Only galvanic isolation provides protection for very large potential differences

Why Isolation?
Common Mode Noise



Basic/Functional Isolation vs. Reinforced Isolation

“An improved basic insulation with such mechanical and electrical properties that, in itself, the insulation provides the same degree of protection against electrical shock as double insulation. It may consist of one or more layers of insulation material.” [UL-60950-1]

Basic/Functional Isolation vs. Reinforced Isolation (cont'd)

When is Reinforced required:

- **6kVpp systems (e.g. 600V IGBTs/FETs)**
- **Today: all Medical applications (5kVrms!)**
- **Future: Medical applications for isolation from the patient**

Note: this is not complete and subject to change. Exceptions may apply!

Basic/Functional Isolation vs. Reinforced Isolation (cont'd)

Note: there used to be a ratio between continuous and transient voltage, e.g. 560Vpk/4kVpk or 891Vpk/6kVpk

This is not the case any more:

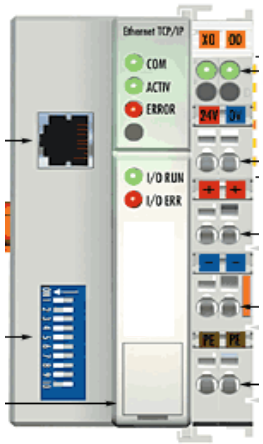
We can offer e.g. 1200Vpk (continuous) with 4kVpk (transient) i.e. 1200Vpk basic isolation

Often sufficient e.g. for inverters

Applications utilizing Isolation

Industrial:

- **Robotics**
- **PLC input/output isolation**
- **Industrial networks**
- **Motor control**
- **Power supplies**

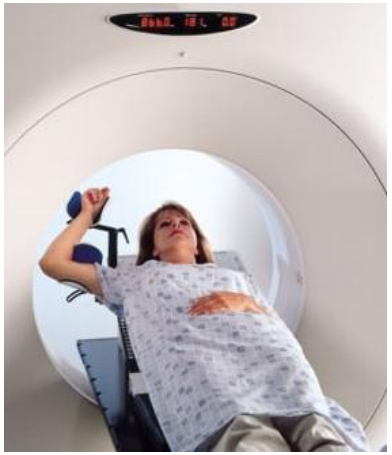


Primary Task:
Isolation between High-Power and Control Signals
Isolation of Bus-Nodes to prevent Corruption
of the complete Bus & Common Mode Rejection

Applications utilizing Isolation

Medical:

- Microwave therapy
- Patient monitoring
- Electrocardiographs
- Defibrillators



Primary Task:
Medical:
Isolation between Power and Patient
Communications:
Isolation between Power and Caller
Isolation of Bus-Nodes to prevent
Corruption of the complete Bus

Communications:

- PBX (Private Branch Exchange) and central office
- Telephone terminal equipment
- Telephone switching equipment
- Modems
- ISDN
- Ethernet / PoE

Applications utilizing Isolation

Consumer Electronics:

- Video (TV, VCR, etc.)
- Plasma displays
- Electronic gaming
- Home appliances

Primary Task:
Isolation between High-Power and User

Computers & Office Equipment

- Isolated I/O
- Printers and plotters
- Fax machines

Nomenclatures / Definitions (1/3)

- Operation Voltage:

Voltage that may be applied continuously across the Isolation barrier, mostly 560Vpk, 890Vpk, 1200Vpk

- Transient Voltage:

Voltage that may occur temporarily across the barrier (tested per VDE for 1 minute), mostly 4kVpk (relates to 3kVrms per UL, as tested for 10s only) or 6kVpk

- Surge Voltage

Single event surge, with the assumption that all effects have been recovered from prior to another surge-event, mostly rated for a 10kV single peak.

Nomenclatures / Definitions (2/3)

- Basic / Functional Isolation:

Assumes a single level of isolation with a certain strength. Applicable for most applications in industrial for fieldbusses and AC-equipment up to 400Vrms, and for consumer electronics. Mostly rated at 560Vpk continuous, 4kVpk transient voltage.

- Reinforced / Double Isolation:

Double Isolation assumes a two-level isolation with a certain strength each. Reinforced addresses a single level of isolation that, however, provides the same reliability as the two-layer. Applicable for most medical applications and AC-equipment above 400Vrms. Mostly rated at 890Vpk continuous, 6kVpk transient , 10kV surge voltage. Medical needs 5kVrms transient.
Intrinsically safe Applications demand double isolation.

Note: the End-equipment-standard (e.g. IEC-60950 for communications or IEC-60601-1 for medical) dictates what is needed on silicon level

Nomenclatures / Definitions (3/3)

- Common Mode Transient Suppression:

Discusses the quick change in Reference potential primary to secondary. It's given as the dU/dt up to which no false toggeling of the output will occur (e.g. 35kV/us). Usually scales ~ linearly with Vcc.

- Creepage and Clearance

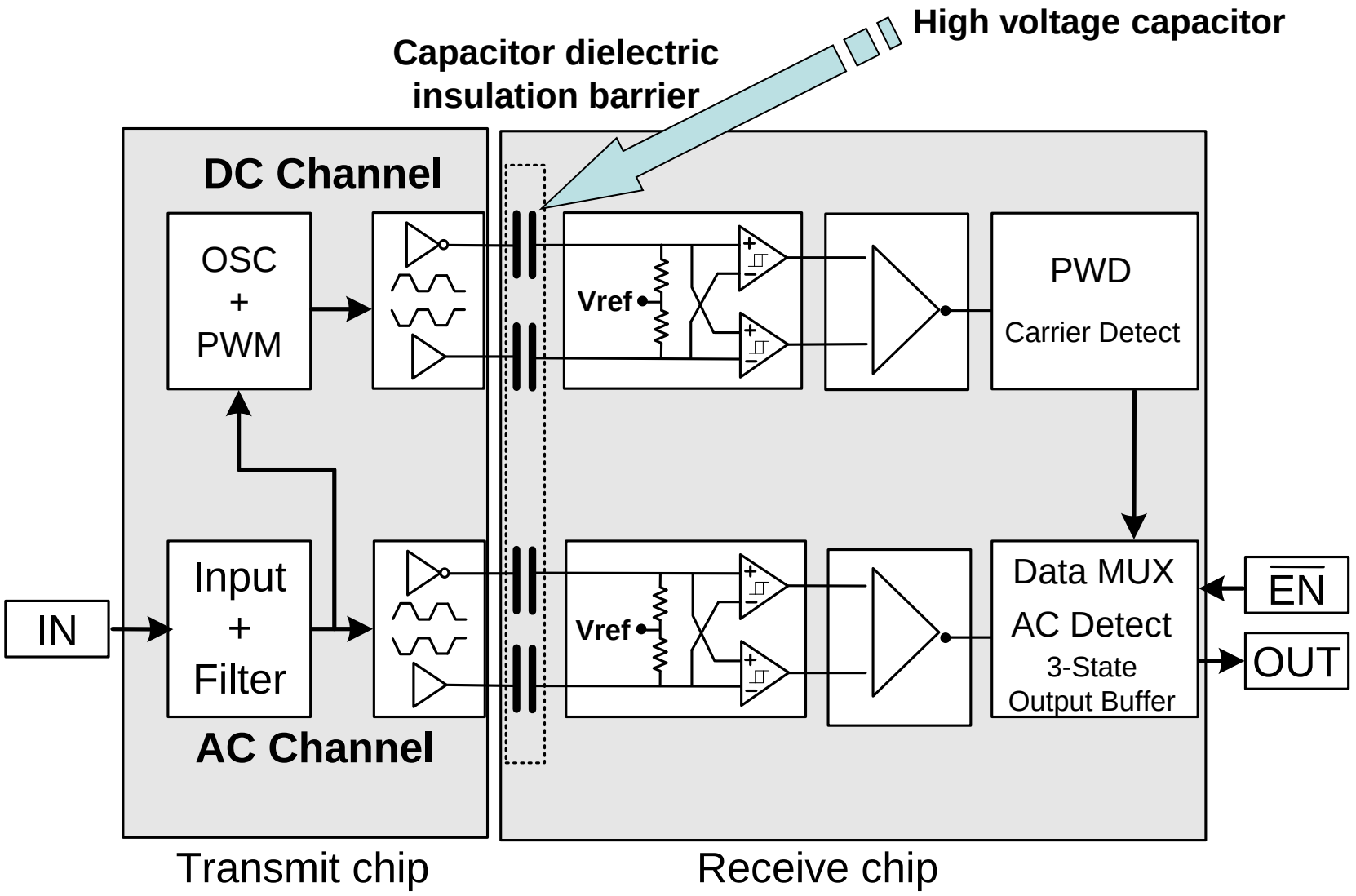
Discusses the surface-distance that may conduct if wet/polluted, respectively the air-distance. For 4kV mostly 4mm is sufficient, for 6kV mostly 8mm is needed. Depends on pollution degree

5 Questions…

… to allow educated solution-proposals

1. **Isolation strength: basic/reinforced? Per UL only or IEC/VDE as well?**
2. **Isolation voltage - continuous: 560Vpeak, 890Vpeak, 1200Vpeak?**
3. **Isolation voltage – transient-overvoltage: 4kVpeak, 6kVpeak, 5kVrms?**
4. **Stand-alone isolation or integration (Transceiver, Gate-Driver, Data-Converter)?**
5. **Supply Voltages?**

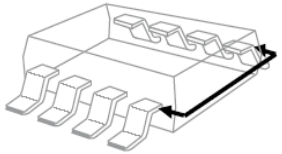
New Generation Capacitive Isolation



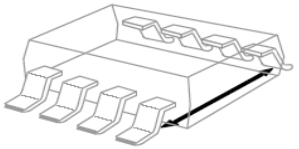
Isolator construction

Creepage distance: Shortest distance between two conductive input to output leads measured along surface of insulation.

Clearance distance: Shortest distance between two conductive input to output leads measured through air (line of sight).

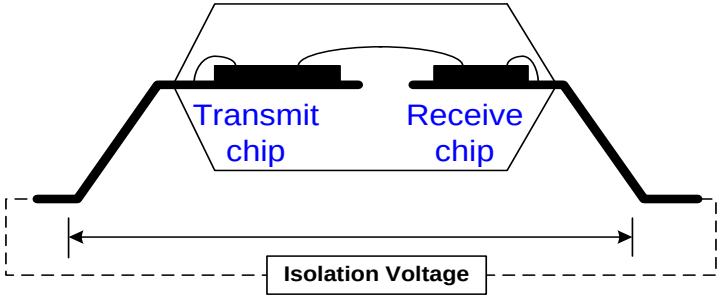


Package/ designation	Creepage mm	Clearance mm
Narrow body SOIC/ D	4.8	4.3
Gull wing / DUB	6.8	6.1
Wide body SOIC/ DW	8.1	8.3

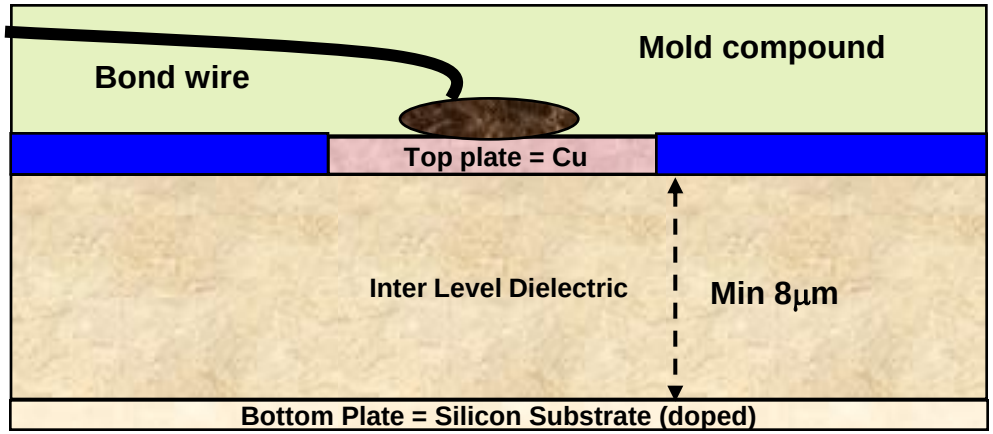


Note: Package-changed and now allows 8.3mm min !

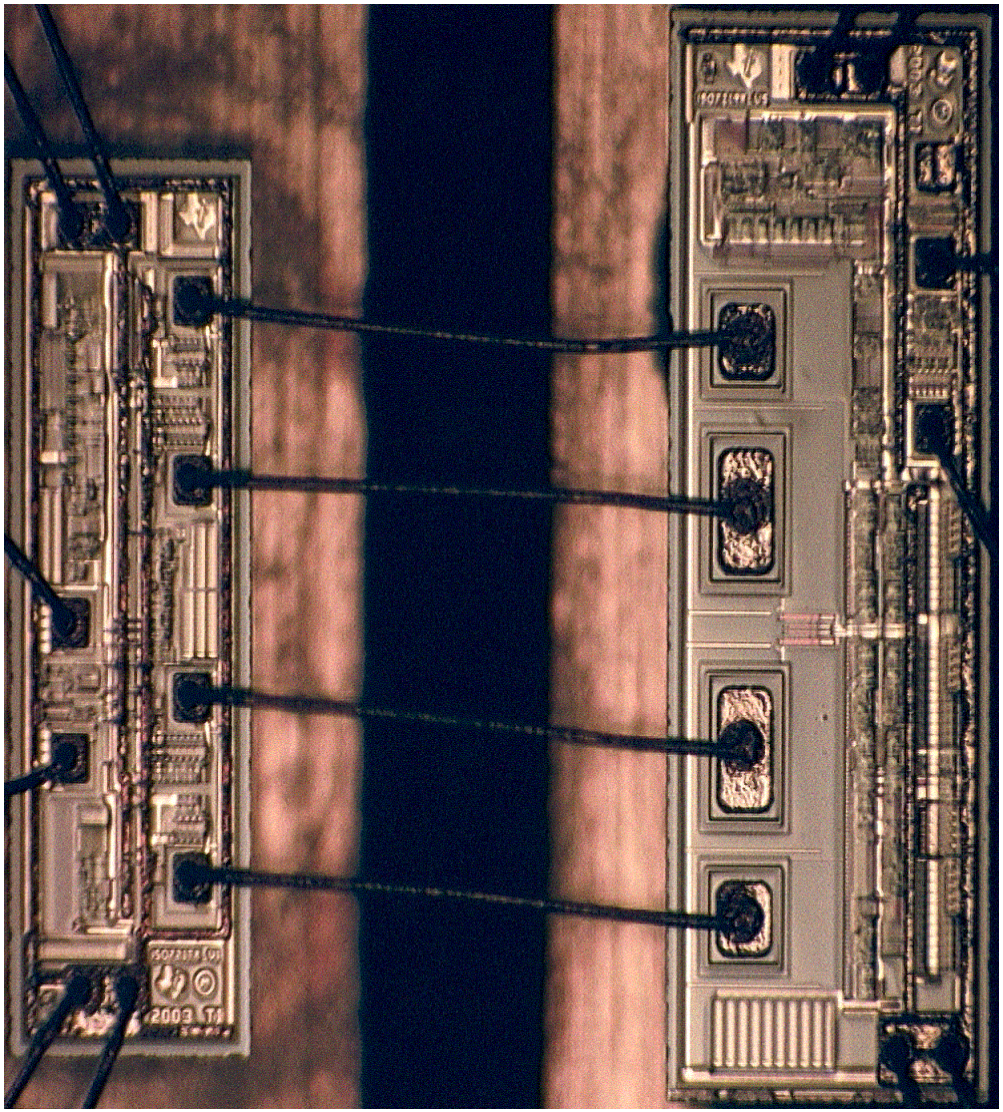
Cross Sectional View



High Voltage Capacitor Construction



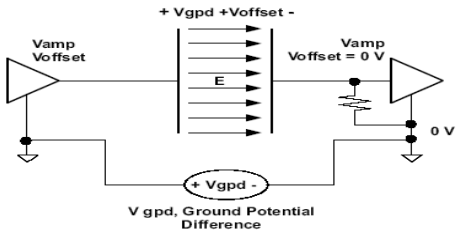
Actual Die-Picture



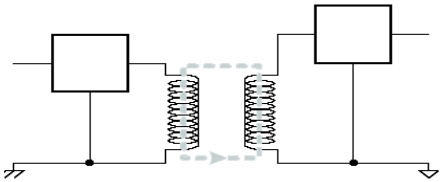
It’s all capacitive

Source: TI App note SLLA198 www.ti.com/iso721

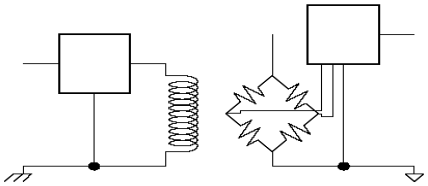
Capacitive



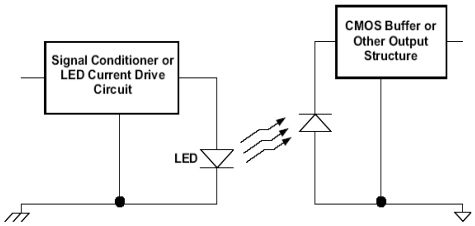
Inductive

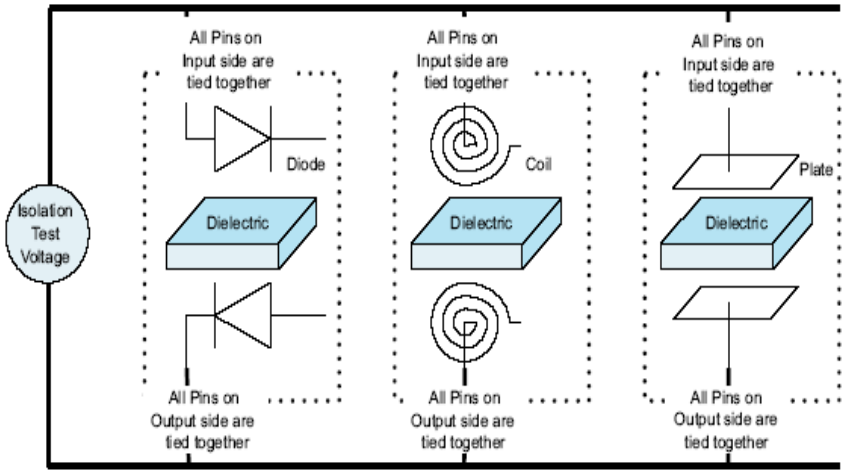


GMR



Optical





	Capa-citive ISO72X	Inductive ADuM1xxx	GMR IL7xx	Optical HCPL-07xx
C_{IO}	1 pF	1 pF	1.1 pF	0.6 pF
ε, material	SiO_2=4.5	Polyimide=2.8	Polyimide=2.8	Mold comp. e=3.6

All isolated couplers can be modeled as I/O and capacitive coupled (active or parasitic)

Timing parameters

	Med.Perf. Opto	HighPerf. Opto	Magnetic	Capacitive
Signaling Rate	Mbps's	50Mbps	150Mbps	150Mbps
Propagation Delay Time	100ns	20ns	32ns	12ns
Pulse Width Distortion	35ns	2ns	2ns	1.5ns
Ch-Ch-skew	40ns	16ns	2ns	1.6ns
Part-Part-Skew	40ns	20ns	10ns	2ns

Competitive Comparison
Reliability (1/2)

	Med.Perf. Opto	HighPerf. Opto	Magnetic	Capacitive
ESD on all Pins	No spec	No spec / 2kV	No spec / 2kV	4kV
CM Transient Immunity	5kV/us	20kV/us	25kV/us	25kV/us
Temperature	-40..85ºC	-40.125ºC	-40.125ºC	-55.125ºC

Competitive Comparison Reliability (2/2)

		60% confidence		90% confidence	
Tech-nology	Ambient Temp.	MTTF [years]	FIT	MTTF [years]	FIT
Capa-citive	125oC	5639	21	2255	50
	55oC	439520	0.3	175808	0.7
Magnetic	125oC	3358	34	1746	65
	55oC	260825	0.44	135606	0.84
Optical	125oC	20	5727	8	14391
	50oC	290	394	115	990

Sample size / failures: ISO721: 45447 / 0; ADuM1201: 35411 / 1; HCPL-0721: 160 / 0

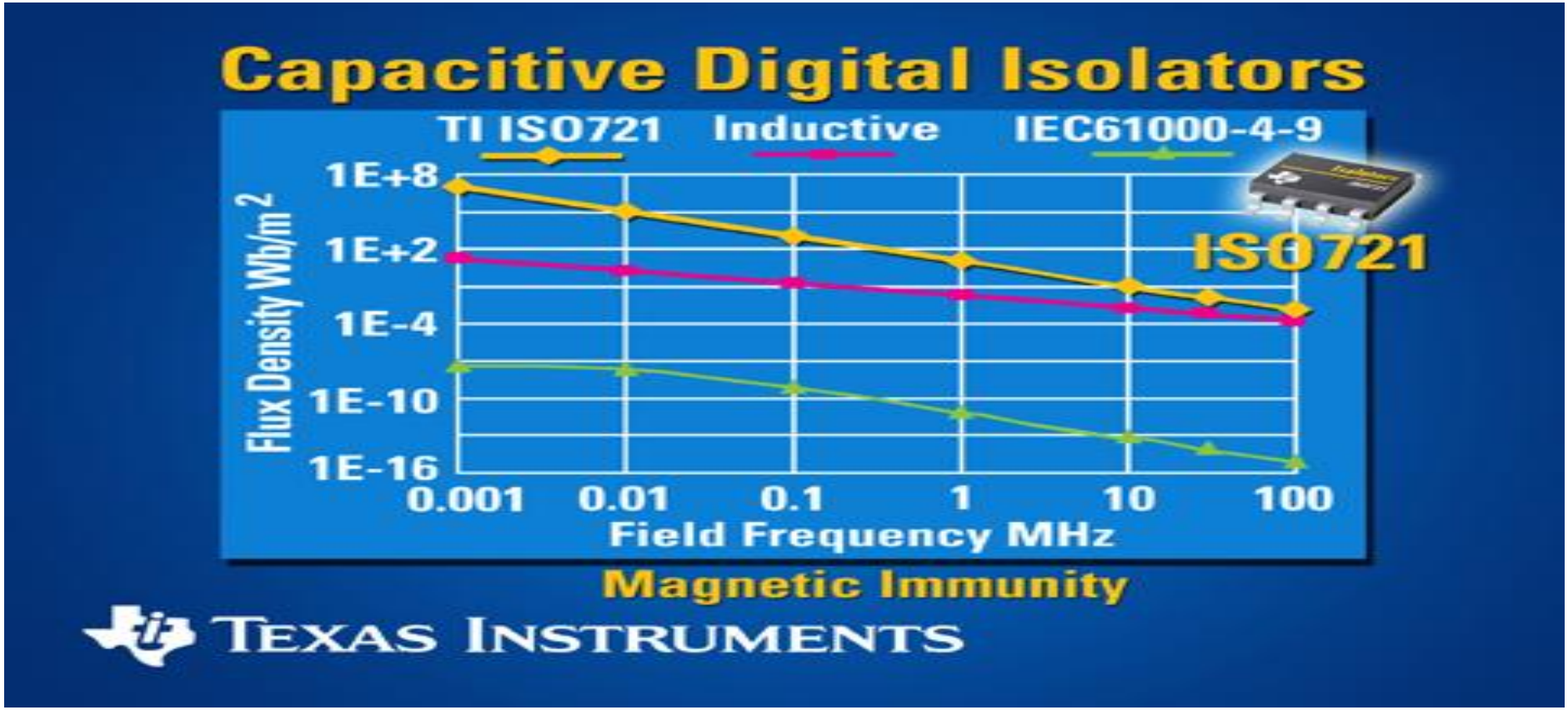
Competitive Comparison
Magnetic Immunity

IEC 61000-4-8

- **1KHz Field Frequency**
- **10^6 x higher Immunity than ADUM1100**

Source: TI App note SLLA181A **www.ti.com/iso721**

(Click on above link for web info)

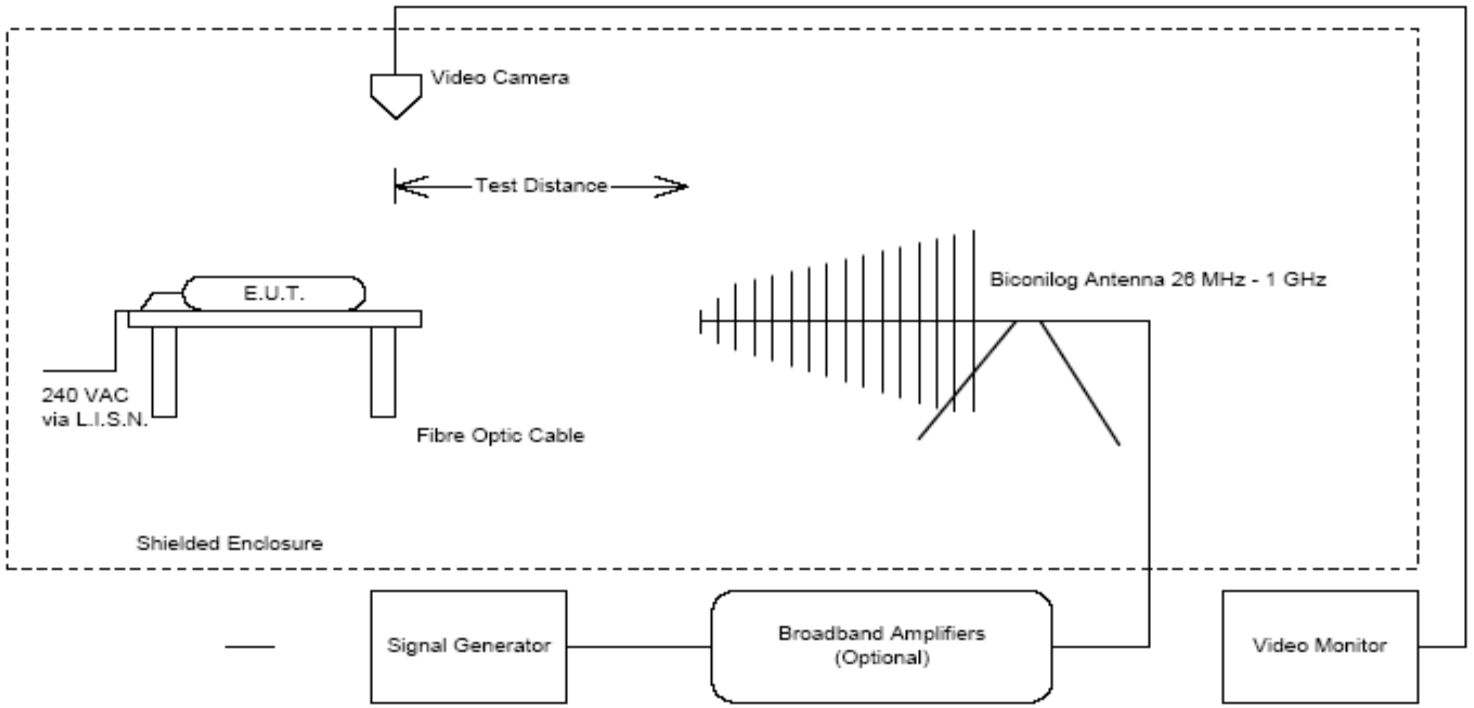


E-field immunity Test Report

Nemko

EN55024
REPORT NO.8289EEU1Rev1
EQUIPMENT: 7221C, 1201CRZ

Test Configuration - Radiated Electromagnetic Immunity (Shielded Room)



Texas Instruments

E-field immunity Test Report

Nemko

EN55024
REPORT NO.8289EEU1Rev1
EQUIPMENT: 7221C, 1201CRZ

Abstract: Immunities: **ISO7221C**
EUT X7221C

Name of Test	Basic Standard	Test Specification	Results
Radiated Electro-magnetic Field	IEC61000-4-3: 1995	80MHz to 1000 MHz 80% AM @ 1 kHz Level X 100 V/M	Complies
Radiated Electro-magnetic Field RS103	MIL-STD 461E RS103	2MHz to 30 MHz 50% AM @ 1 kHz 200 V/M	Complies
Radiated Electro-magnetic Field RS103	MIL-STD 461E RS103	30MHz to 1000 MHz 50% AM @ 1 kHz 100 V/M	Complies

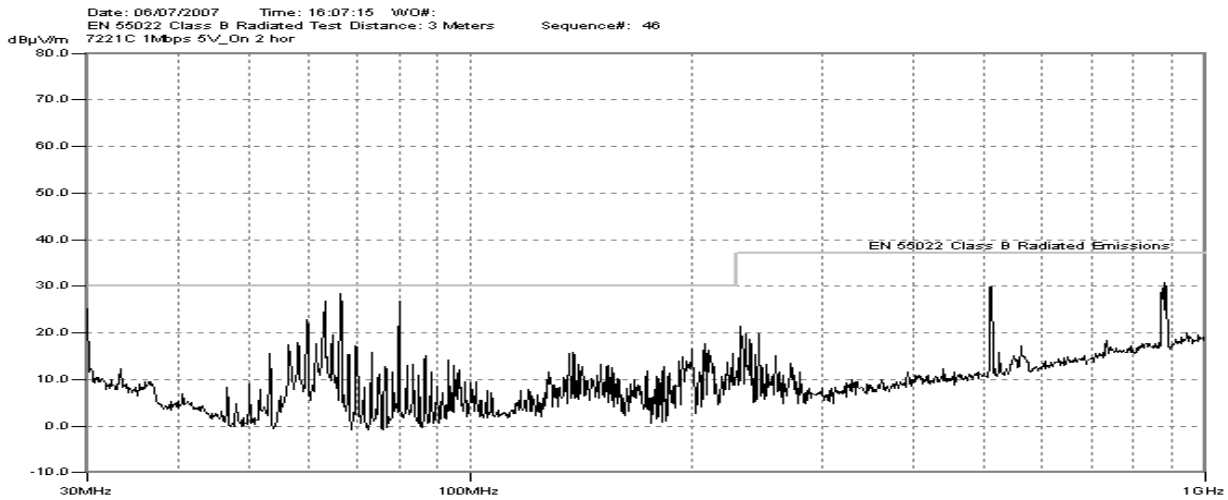
Abstract: Immunities: **Magnetic**
EUT 1201CRZ

Name of Test	Basic Standard	Test Specification	Results
Radiated Electro-magnetic Field	IEC61000-4-3: 1995	80MHz to 1000 MHz 80% AM @ 1 kHz Level X 100 V/M	Fails
Radiated Electro-magnetic Field RS103	MIL-STD 461E RS103	2MHz to 30 MHz 50% AM @ 1 kHz 200 V/M	Complies
Radiated Electro-magnetic Field RS103	MIL-STD 461E RS103	30MHz to 1000 MHz 50% AM @ 1 kHz 100 V/M	Fails

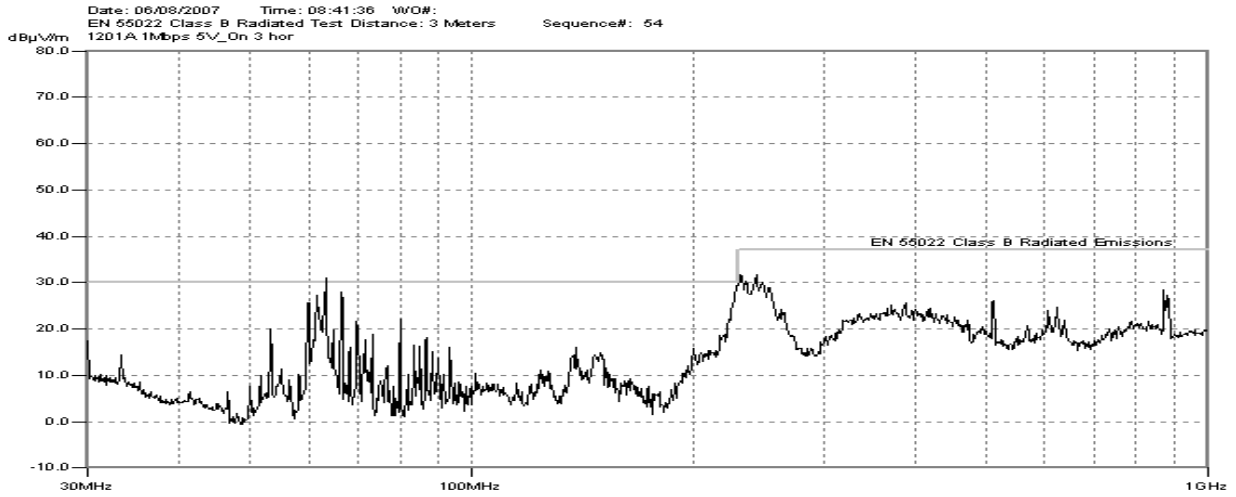
EN55022 Class B Radiations Testing

1Mbps: Comparison of Radiated Noise Spectrum – Antenna Horizontal

ISO7221: 1Mbps operation @ 5V Vcc



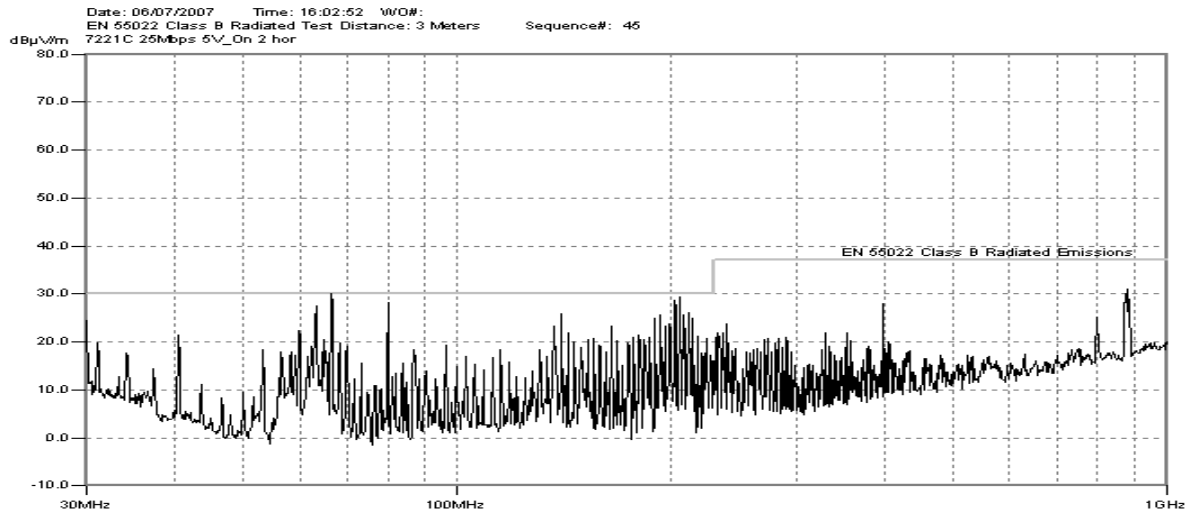
Magnetic: 1Mbps operation @ 5V Vcc



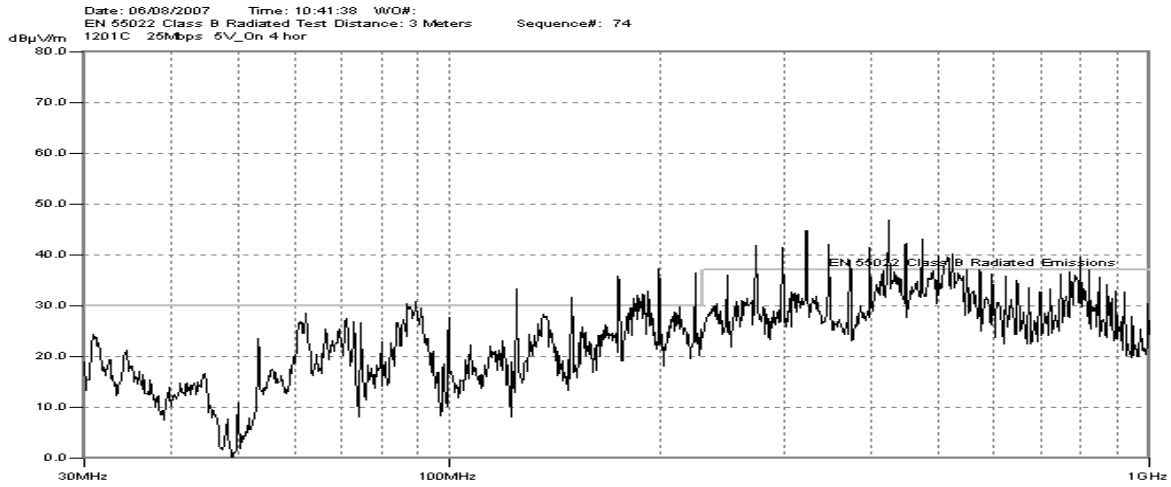
EN55022 Class B Radiations Testing

25Mbps: Comparison of Radiated Noise Spectrum – Antenna Horizontal

ISO7221: 25Mbps operation @ 5V Vcc

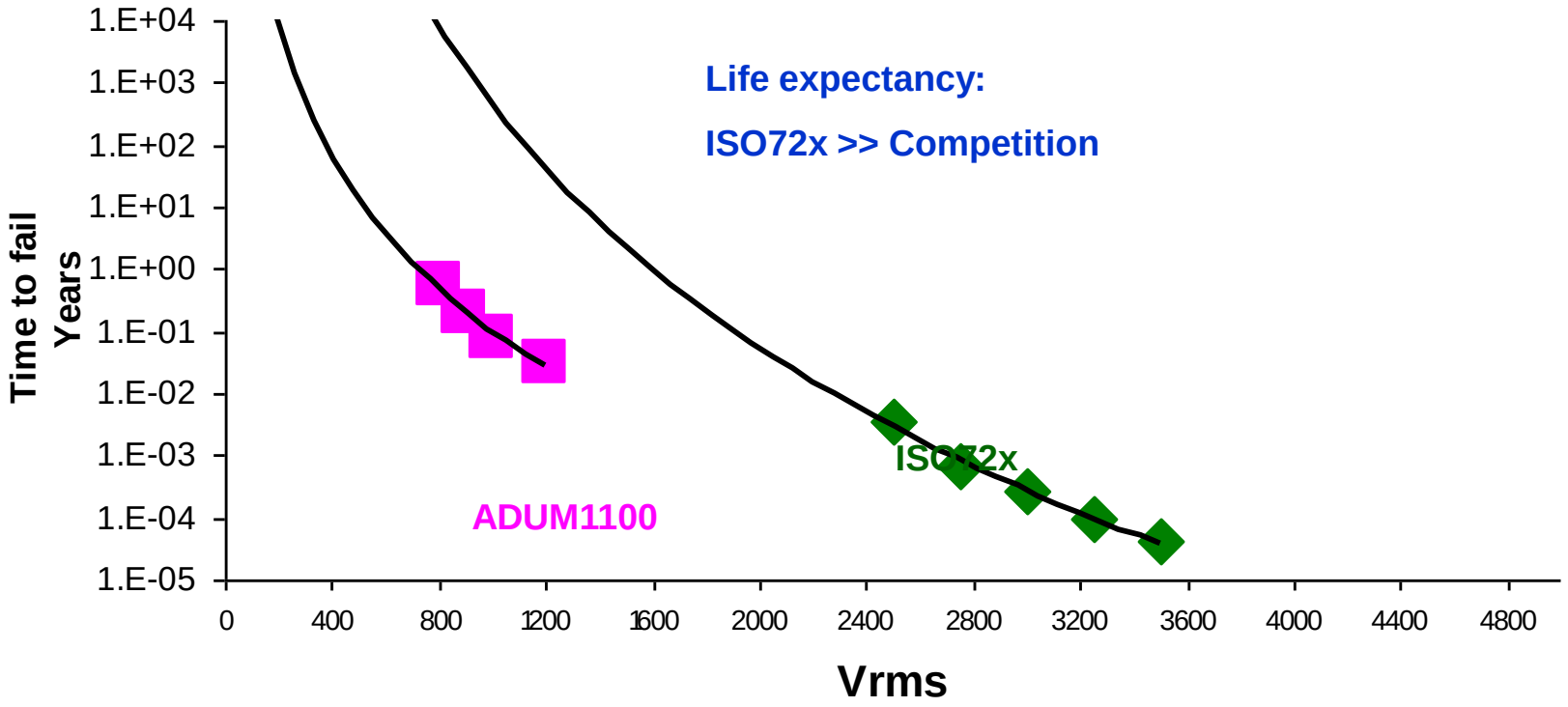


Magnetic: 25Mbps operation @ 5V Vcc

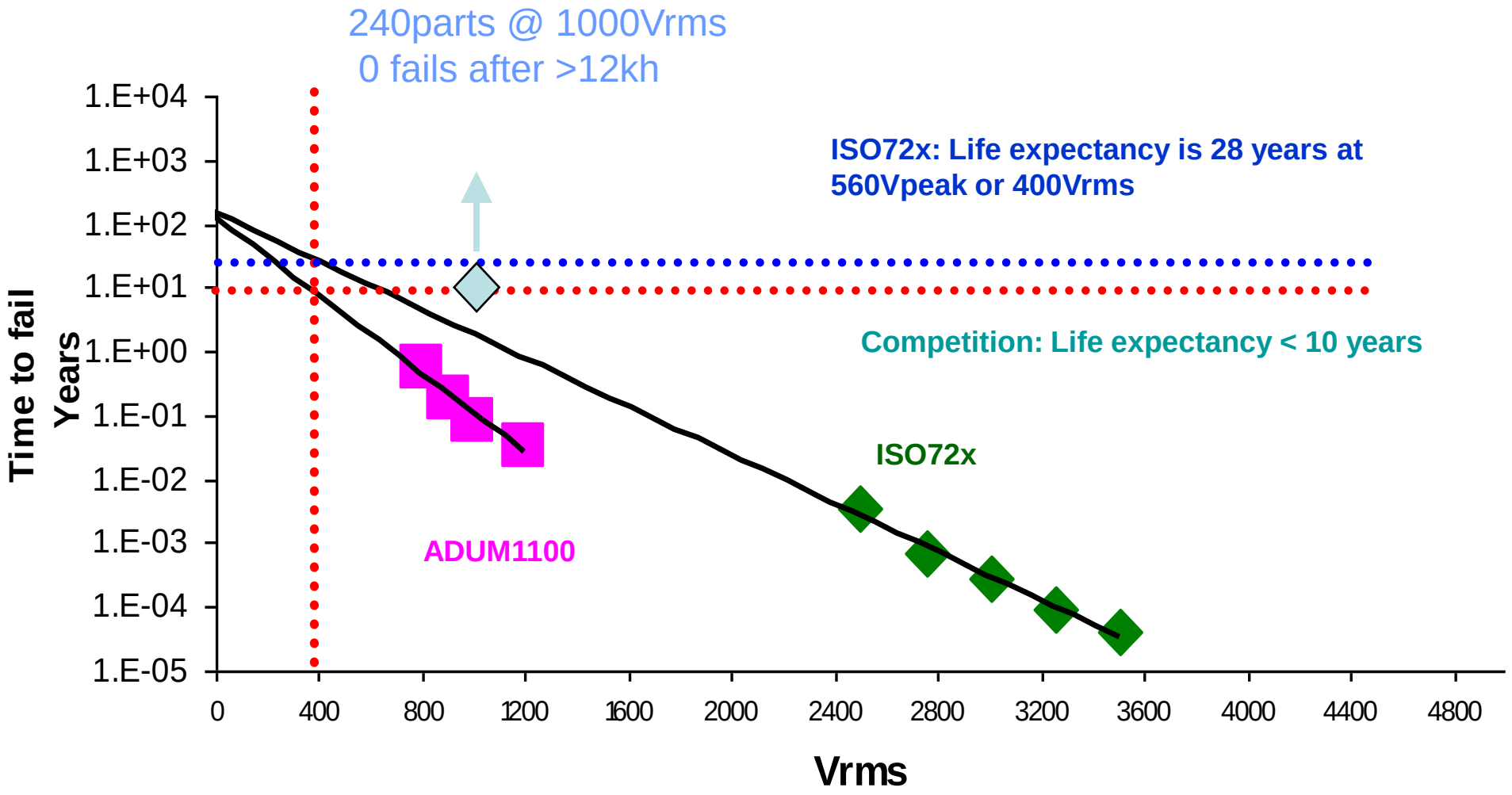


Competitive Comparison
High Voltage Lifetime

Source: TI App note SLLA197 www.ti.com/iso721



Competitive Comparison
High Voltage Lifetime
Using widely accepted E-Model methodology



Icc Comparison

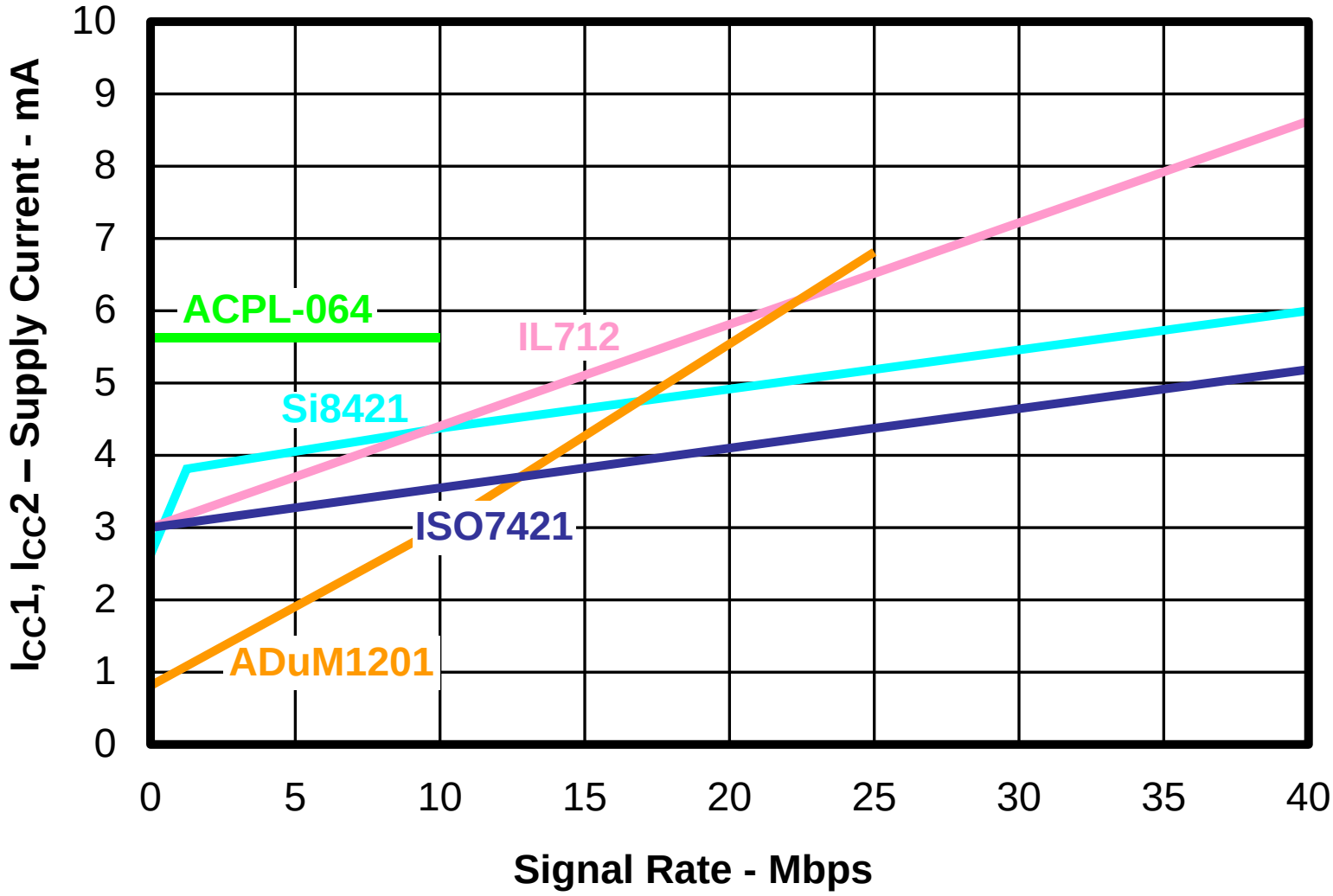
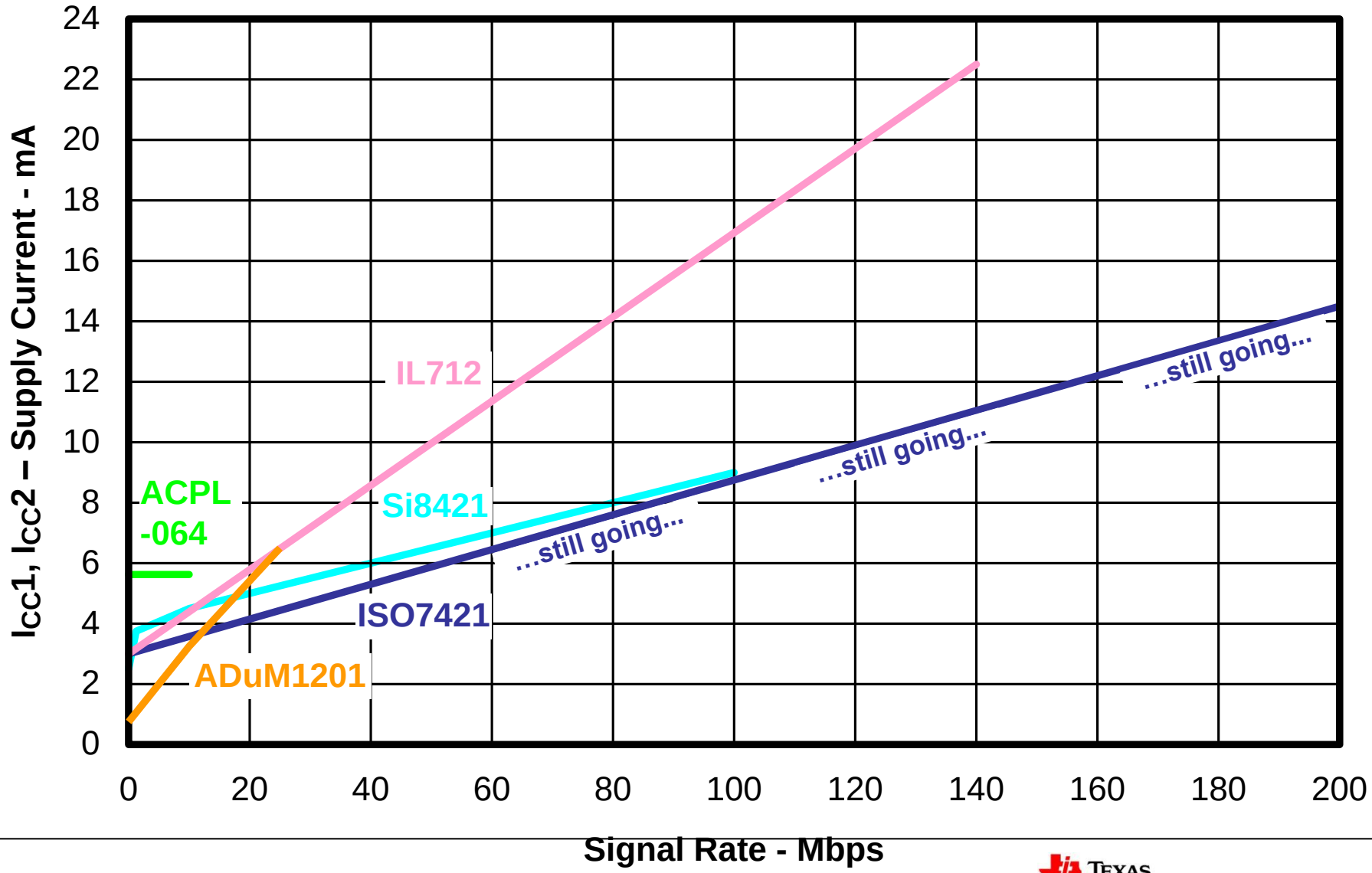


Figure of Merritt: Bandwidth per Supply Current



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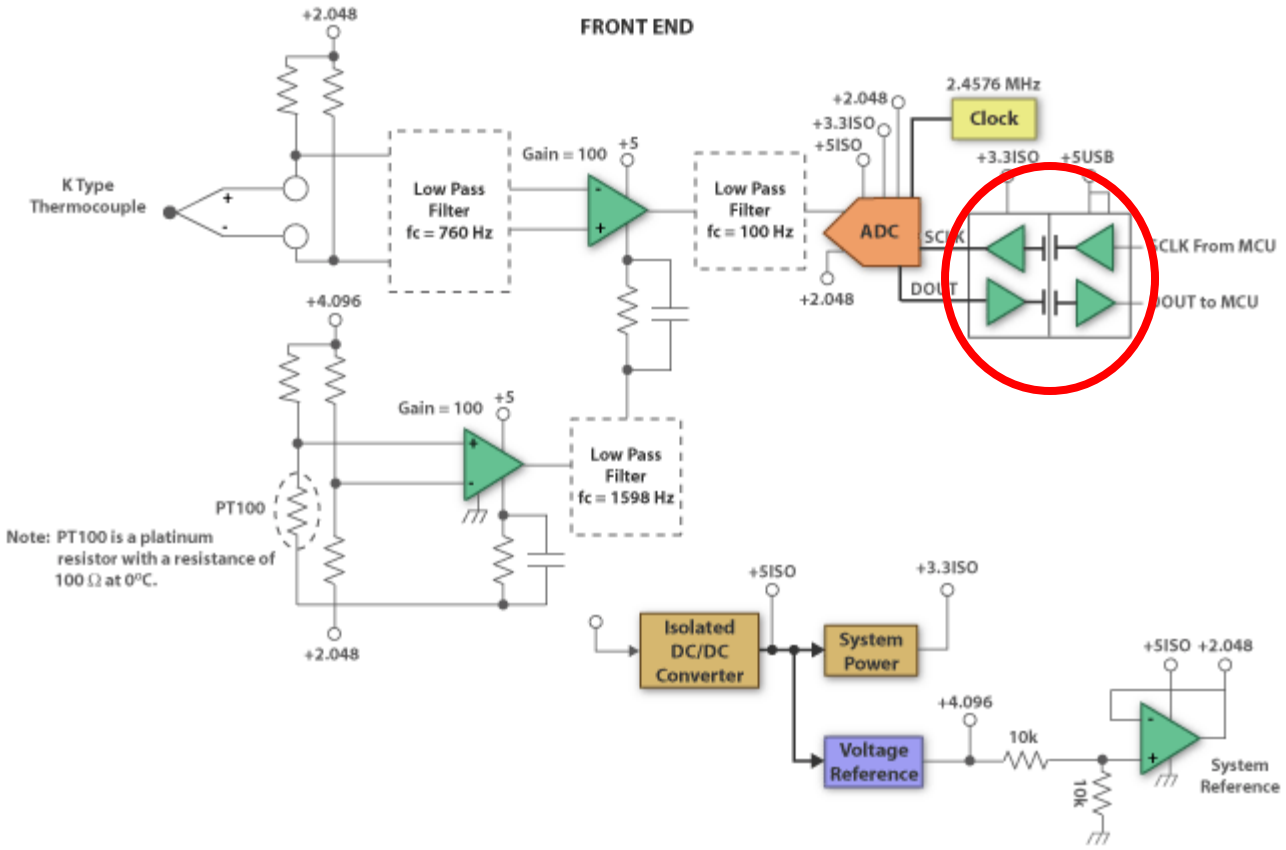
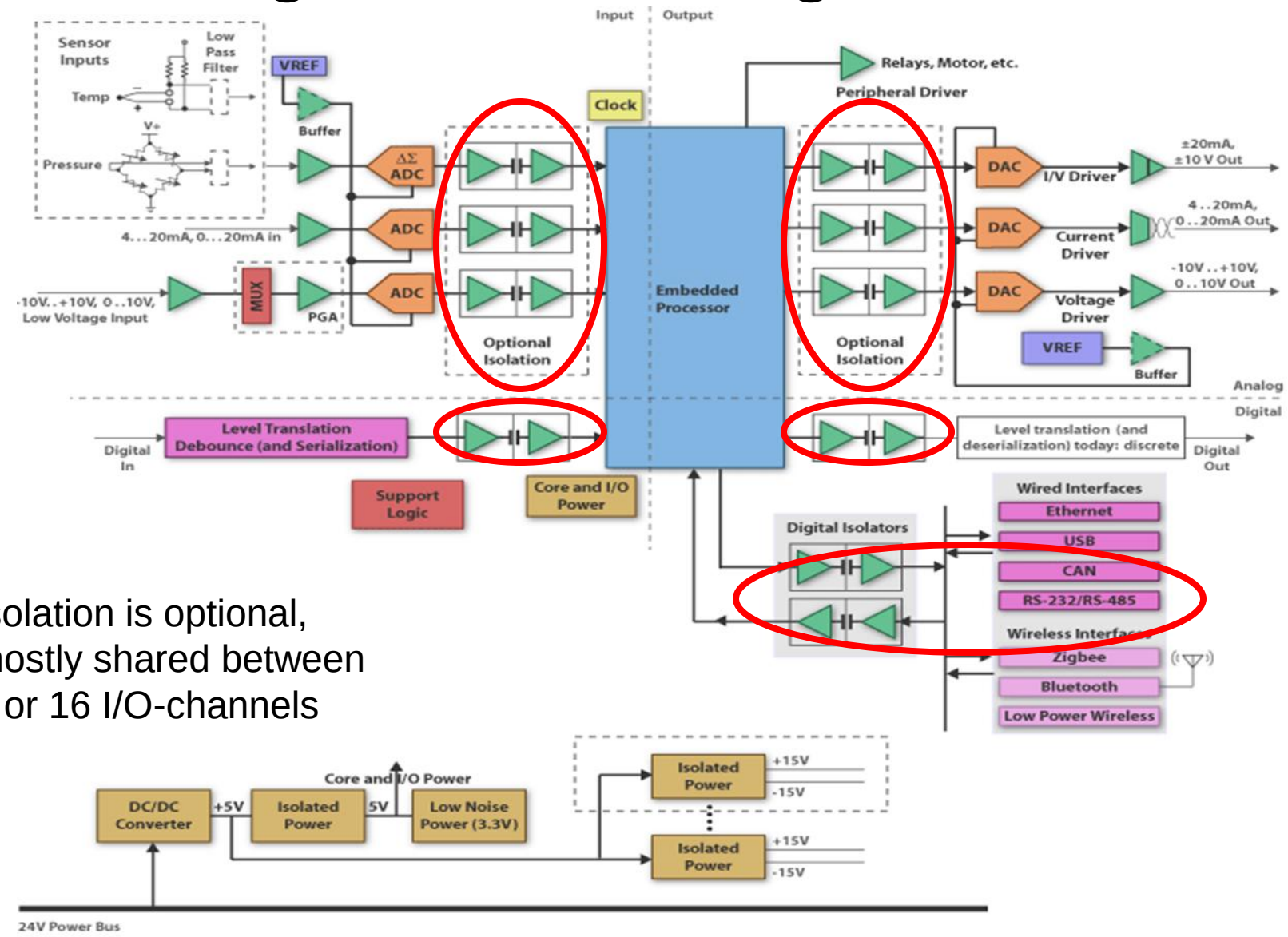
Isolated Thermocouple

Thermocouples may be placed in harsh, high voltage environments,
e.g. winding-temperature in Motors or Transformers
In case of a short, obviously, neither the uC nor the user likes to “see” such voltages



Programmable Logic Controller



Isolation is optional,
mostly shared between
8 or 16 I/O-channels

Isolated Products – Stand-Alone

Available today

Singles	Duals	Triples	Quads
ISO721/M ISO722/M	ISO7220A/B/C/M ISO7221A/B/C/M	ISO7230A/C/M ISO7231A/C/M	ISO7240A/C/M ISO7241A/C/M ISO7242A/C/M

560Vpk (cont'); 4kV pk (transient)

(Click on Product for more information)

	Duals	Triples	Quads
560Vpk (cont') 4kV pk (transie	ISO7420 ISO7421	ISO7430 ISO7431	ISO7440 ISO7441
1200Vpk+ (con 5kVrms reinforce per UL (transient)	ISO7520 ISO7521	ISO7530 ISO7531	ISO7540 ISO7541

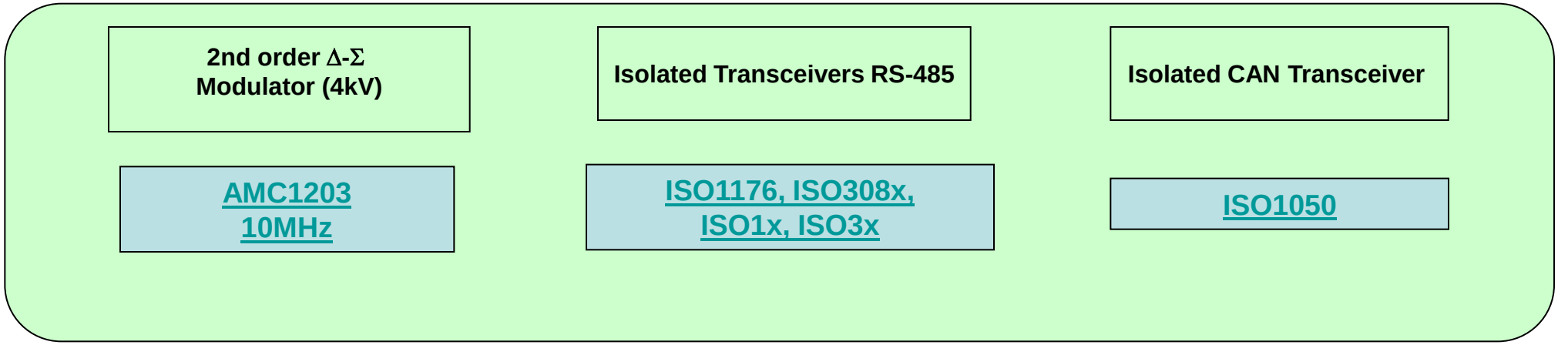
ISO7421: Available

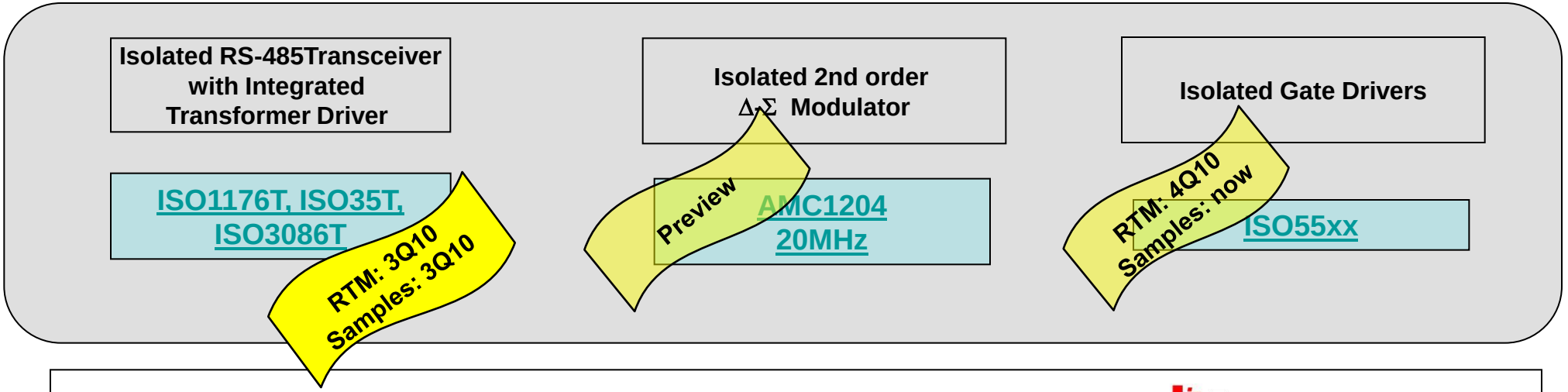
ISO7521: Samples: now RTM: 2Q10

RTM: tbd
Samples: tbd

Low-Power-versions, in development, pin-compatible with ISO72xx

Isolated Products – Integrated





Texas Instruments

ISO74xx Family

2/3/4 channel Low Power Digital Isolators

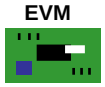
- Silicn Integrated SiO_2 Dielectric Capacitor
- 0–25Mbps and DC Signal Pass with Fail Safe
- 2ns Skew, 3ps Pulse Distortion, 9ns Delay
- Low Power – 1.5mA per channel typical
- High Magnetic Immunity (1E6 > Inductive)
- 4KV ESD on All Pins
- 3V and 5V Supply Support
- 4000V PEAK / 2500V RMS transient overvoltage
- 560V PEAK continuous voltage
  - Wide and Narrow SOIC Packages
  - UL1577, IEC 60747-5-2
    IEC 61010-1 & CSA pending

- Proven Reliability of SiO_2 Dielectric,
  - Life Span > 25 years
- Lowest Skew, & Pulse Width Distortion
- Enabling low power application
- High Immunity for Noisy Environments
- High Reliable in Harsh Environments
- Flexibility with Power Supplies
- Certified by all 3 World Wide agencies

Consumer: Computer peripherals

- Industrial Controls
  - PLC, Servo, Motor Control, Sensors
  - Industrial Automation
  - Fieldbus – Modbus, Profibus, DeviceNet Data Buses, CAN, RS485
- Power Supply/Regulation Systems
- Automotive Electronics & Hybrid Vehicles

Part #	Channel	Temp C	Packages	Samples // RTM
ISO7420	2/0	-40 to 105	SOIC	Released
ISO7420M	2/0	-55 to 125	SOIC	Released
ISO7421	1/1	-40 to 105	SOIC	Released
ISO7421M	1/1	-55 to 125	SOIC	Released
ISO7431	2/1	-40 to 105	SOIC	2Q// 3Q
ISO7431M	2/1	-55 to 125	SOIC	2Q // 3Q
ISO7440	4/0	-40 to 105	SOIC	2Q // 3Q
ISO7440M	4/0	-55 to 125	SOIC	2Q // 3Q
ISO7441	3/1	-40 to 105	SOIC	2Q // 3Q
ISO7441M	3/1	-55 to 125	SOIC	2Q // 3Q



ISO EVM - ISO72xxEVM

ISO75xx Family

2/3/4 channel *5kV RMS* Digital Isolators

- Silicon Integrated SiO_2 Dielectric Capacitor
- 0–25Mbps and DC Signal Pass with Fail Safe
- 2ns Skew, 3ps Pulse Distortion, 9ns Delay
- Low Power – 1.5mA per channel typical
- High Magnetic Immunity (1E6 > Inductive)
- 4KV ESD on All Pins
- 3V and 5V Supply Supported
- 4000V PEAK transient overvoltage (per VDE/IEC)
- 5000V RMS transient overvoltage (per UL)
- 1200V PEAK continuous voltage (per UL & VDE/IEC)
  - Wide Body SOIC with 8.1mm Creepage
  - UL1577, IEC 60747-5-2, Medical IEC 60601-1 IEC 61010-1 & CSA pending

- Proven Reliability of SiO_2 Dielectric,
  - Life Span > 25 years
- Lowest Skew, & Pulse Width Distortion
- Enabling low power application
- High Immunity for Noisy Environments
- High Reliable in Harsh Environments
- Flexibility with Power Supplies
- Certified by all 3 World Wide agencies

- Medical
- Consumer: Computer peripherals
- Industrial Controls
  - PLC, Servo, Motor Control, Sensors
- Industrial Automation
  - Fieldbus – Modbus, Profibus, DeviceNet Data Buses, CAN, RS485
- Power Supply/Regulation Systems
- Automotive Electronics & Hybrid Vehicles

Part #	Channel	Temp C	Samples // RTM
ISO7520	2/0	-40 to 105	2Q // 2Q
ISO7520M	2/0	-55 to 125	2Q // 2Q
ISO7521	1/1	-40 to 105	2Q // 2Q
ISO7521M	1/1	-55 to 125	2Q // 2Q
ISO7531	2/1	-40 to 105	2Q// 3Q
ISO7531M	2/1	-55 to 125	2Q // 3Q
ISO7540	4/0	-40 to 105	2Q // 3Q
ISO7540M	4/0	-55 to 125	2Q // 3Q
ISO7541	3/1	-40 to 105	2Q // 3Q
ISO7541M	3/1	-55 to 125	2Q // 3Q

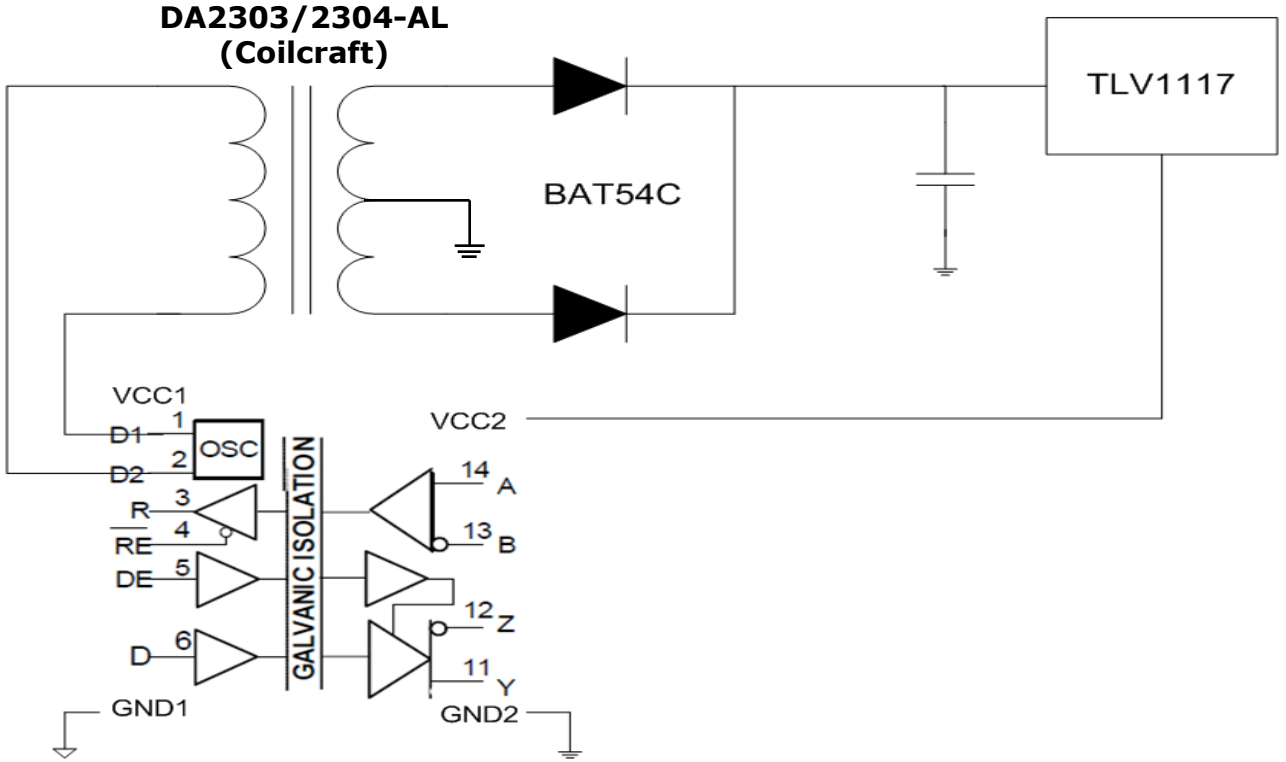
EVM

ISO EVM - ISO72xxEVM

ISO – 485 with Transformer Driver - preview

Simple Complete Solution - ISO1176T / ISO35T / ISO3086T

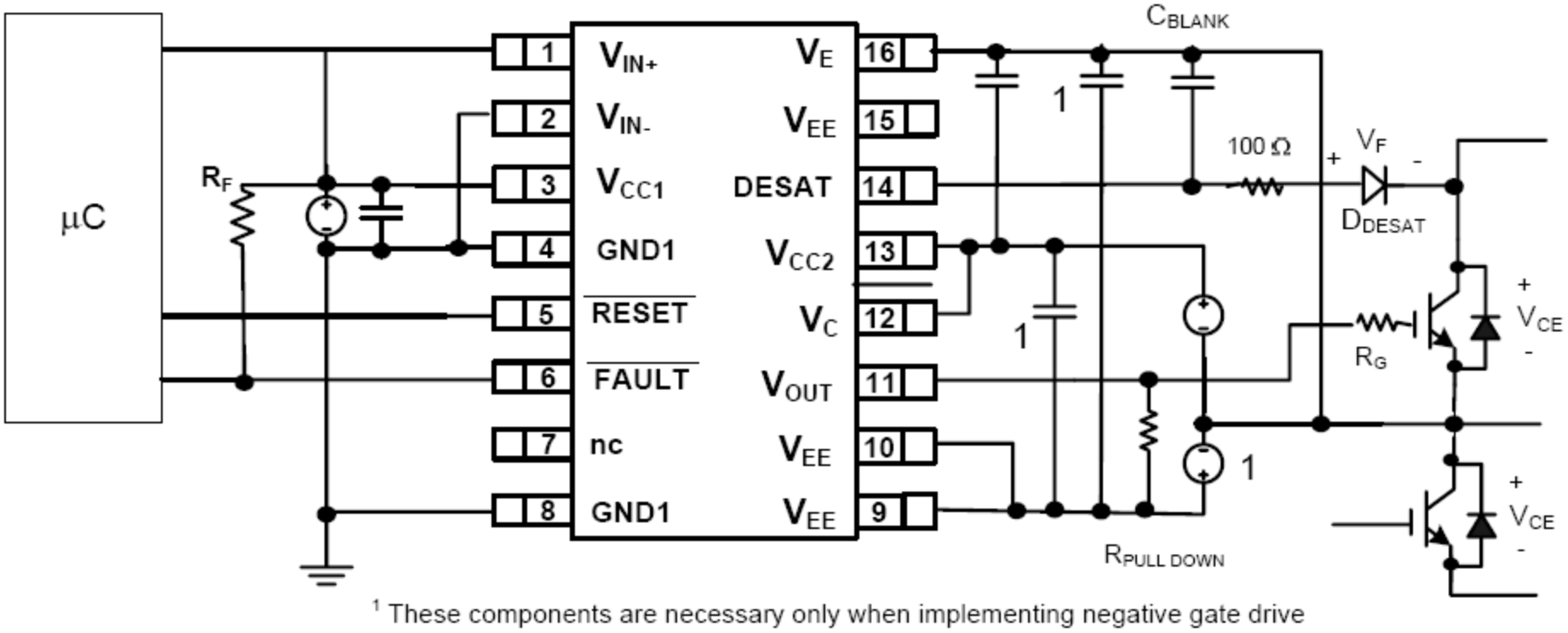
- 1Mbps / 20Mbps /40Mbps
- 1/8 Unit load – 256 nodes on a bus
- Glitch-Free
- Failsafe (Open, Shorted, Idle)
- Silicon Integrated SiO_2 Insulator
- 4kVpk / 2500Vrms Isolation,
  560V working / operating
- UL1577,
  IEC 60747-5-2 (VDE 0884, rev. 2)
  IEC 61010-1 & CSA pending



EVM – ISO1176TEVM / ISO35TEVM / ISO3086TEVM

Isolated Gate Drivers (IGBT / MOSFET) - preview

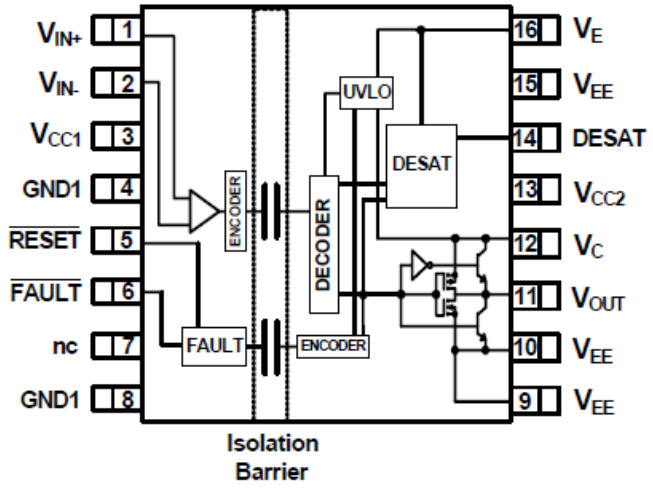
1200Vpk, 2.5A



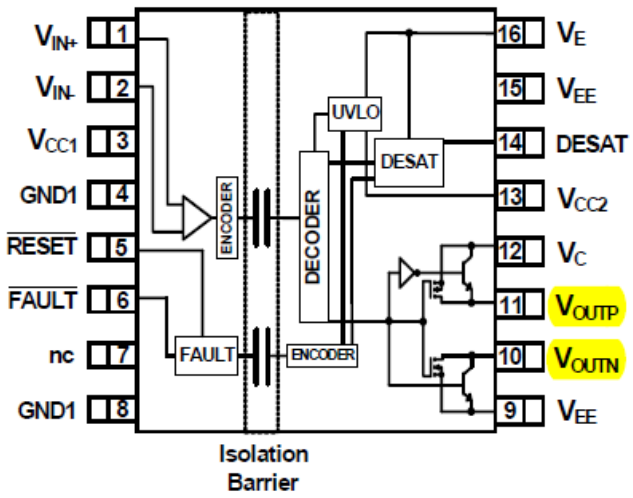
[1] These components are necessary only when implementing negative gate drive

Isolated Gate Drivers (IGBT / MOSFET) cont'

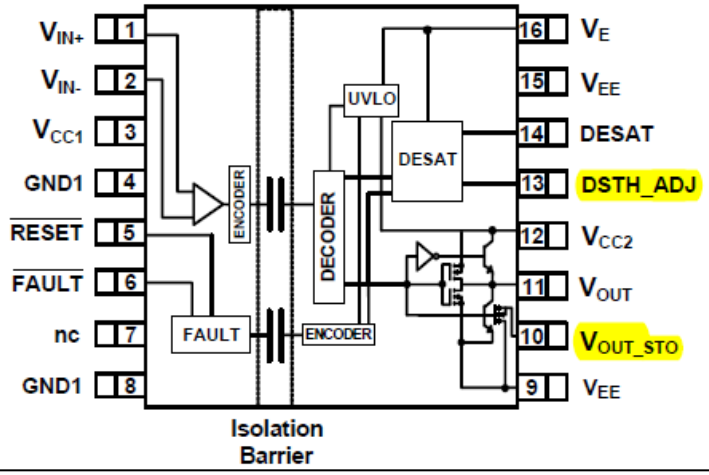
ISO5500



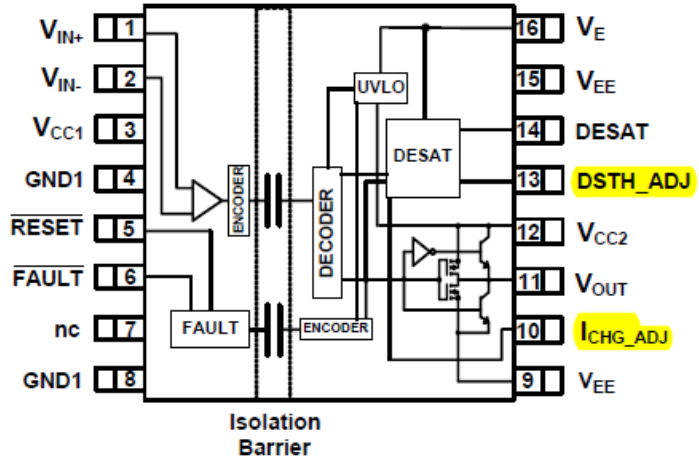
IS5501



ISO5510, ISO5511

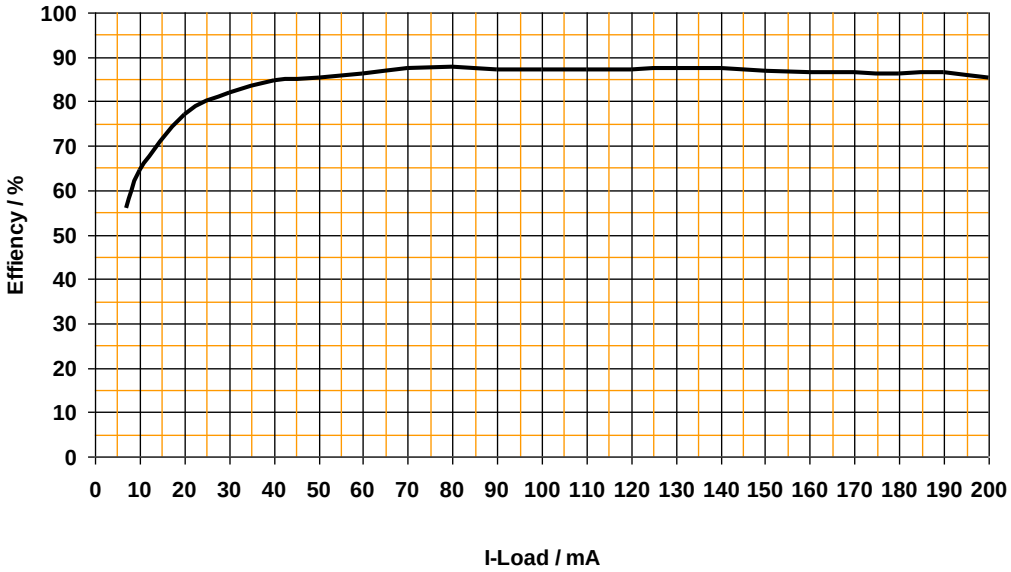


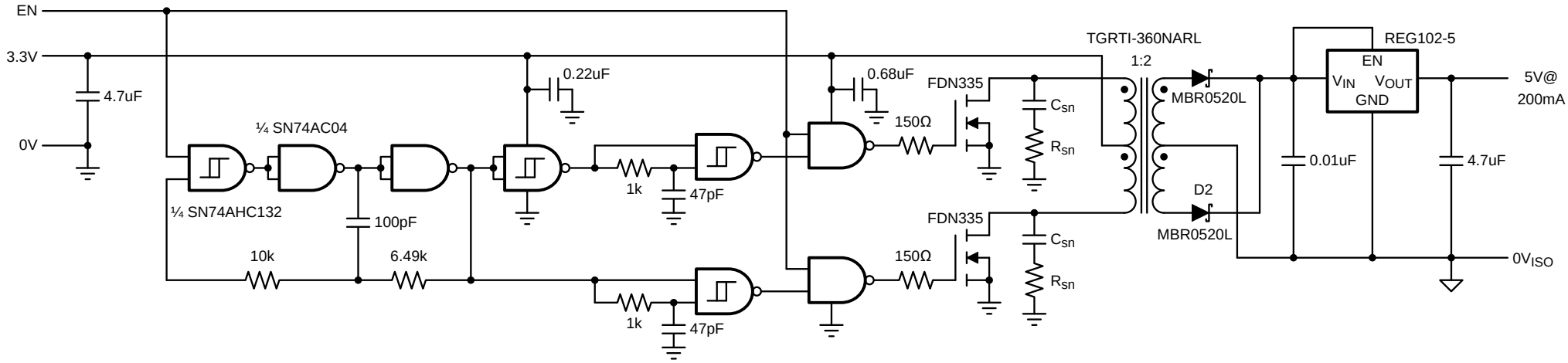
ISO5512, ISO5513



Low-Cost Isolated Power Supply

- Low-Cost (~ $5.50)
- High Efficiency (~87%)
- Regulated Output (Short-Circuit Protected)
- For Isolation Transformers (1kV – 6kV)
- Vin = 3.3V ± 10%
- Adjustable Vout from 3.3V to 5.0V
- Iout-max = 700mA @ 3.3V, or 200mA @ 5V

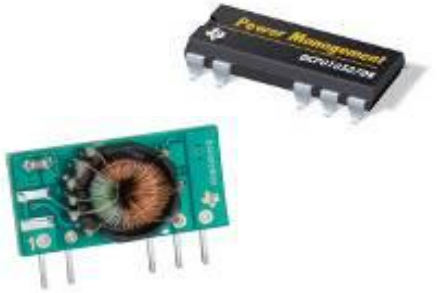




Power Management Products

by Texas Instruments

Power	Model	Isolation Voltage	Input Voltage	Output Voltage	Output Regulation
1W	DCP01B	1000V	5V, 15V, 24V	5V, ±5V, ±7V, 12V, ±12V, 15V, ±15V	No
1W	DCV01	1500V	5V, 15V, 24V	5V, ±5V, 12V, ±12V, 15V, ±15V	No
1W	DCR01	1000V	5V, 15V, 24V	3.3V, 5V	Yes
1W	DCH01	3000V	5V	5V, ±5V, 12V, ±12V, 15V, ±15V	No
2W	DCP02	1000V	5V, 12V, 15V, 24V	3.3V, 5V, ±5V, 7V, 9V, 12V, ±12V, ±15V, ±18V	No
2W	DCR02	1000V	12V, 24V	5V	Yes



- Single and dual outputs
- Dual-in-line, gull-wing, small-outline (SO), and SIP packaging
- Up to 3000V isolation
- Short-circuit protection
- Thermal protection
- Device-to-device synchronization
- -40 to +85 °C temp range
- Surface-mount devices in tape and reel