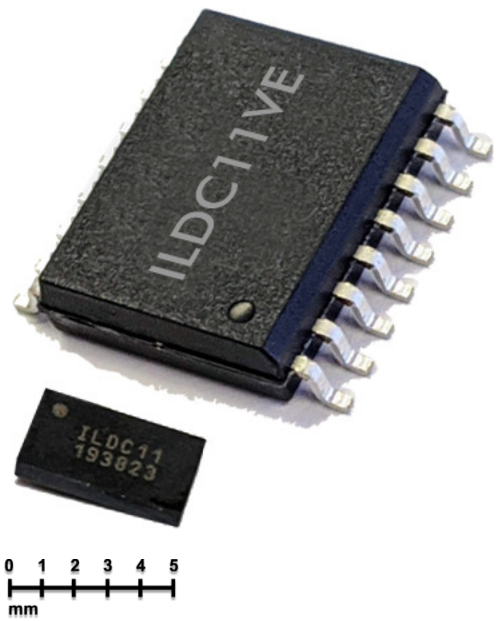
ILDC1x Ultraminiature Isolated DC-DC Convertors



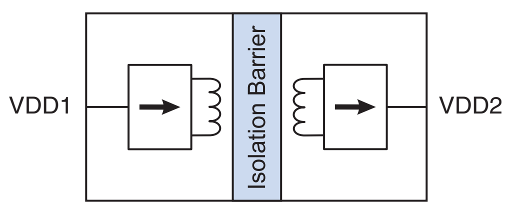
Features

- World's smallest isolated DC-DC convertor
- Ultraminiature 3 x 5.5 x 0.9 mm (0.015 cm³) DFN or 8 mm creepage SOIC16-WB
- 3.3 V input; 3.3 V, 5 V, or 6 V output options
- ¼ W output
- Fully-regulated output
- Option for external regulators
- No minimum load
- Ultralow ripple
- Low EMI without ferrite beads or inductors
- Short-circuit and thermal protection
- 5 kV_{RMS} isolation (2.5 kV_{RMS} for DFN version)
- Full −40 °C to 125 °C operating range with no derating

Applications

- Ground loop mitigation
- RS-485 / RS-422 bus power supplies
- Isolated SPI / Microwire interfaces
- Isolated ADC and DAC power supplies
- Medical instrumentation requiring true 8 mm creepage under IEC 60601 (wide-body SOIC version)

Block Diagram



Description

The ILDC1x family is ultraminiature one-quarter watt fully-regulated 3.3 V input DC-DC convertors that generate an independent, isolated 3.3-volt, 5-volt, or 6-volt supplies.

There are two package options—the ILDC1x-15E ultraminiature 3 mm x 5.5 mm DFN6, and the ILDC1xVE SOIC16-WB. The DFN version is the world's smallest isolated DC-DC convertor at just 0.015 cm³.

The device minimizes board space and parts count, requiring just three external capacitors. No additional regulation is required and there is no minimum load.

The DFN version is rated at a full 2.5 kV_{RMS}, and the SOIC16 has a remarkable 5 kV_{RMS} isolation rating.

A unique ceramic/polymer composite barrier provide virtually unlimited barrier life.

Frequency hopping and shielding reduce EMI and eliminate the need for ferrite beads.

A high-temperature process allows up to 175 °C junction temperature for full power up to 125 °C operating temperature with no derating. Integrated short-circuit protection avoids excessive power dissipation.

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Absolute Maximum Ratings

Parameter	Min.	Max.	Units
Supply voltage	–0.6	6	Volts
Storage temperature	–55	180	°C
Junction temperature	–55	180	°C

Recommended Operating Conditions

Parameter	Symbol	Min.	Typ.	Max.	Units	Test Conditions
Ambient operating temperature	T_{min}; T_{max}	–40		125	°C	
Junction temperature	T_J	–40		175	°C	
Input supply voltage	V_{DD1}	3	3.3	3.6	V	
Output current	I_{DD2}	0		80	mA	

Electrical Specifications

T_{min} to T_{max} and V_{DD1} = 3 V to 3.6 V unless otherwise stated						
Parameter	**Symbol**	**Min.**	**Typ.**	**Max.**	**Units**	**Test Conditions**
Output voltage ILDC11 ILDC12 ILDC13	V_{DD2}	 3 4.5 5.4	 3.3 5 6	 3.45 5.5 6.6	V	T_{min} to T_{max}; full V_{DD1} and I_{DD2} operating range
Output current ILDC11 ILDC12 ILDC13	I_{DD2}	 80 50 41			mA	
Short-circuit protection limited current	$I_{DD2\text{-}SC}$	115	125	135	mA	
Input quiescent supply current	I_{DD1Q}		200	240	mA	I_{DD2} = 0
Input supply current ILDC11 ILDC12 ILDC13	I_{DD1}		 380 312 290	 440 360 340	mA	I_{DD2} = max.
Line regulation	$\Delta V_{DD2}/\Delta V_{DD1}$		32	40	mV/V	25 °C
			16			125 °C
Load regulation	$\Delta V_{DD2}/V_{DD2}$		5	6	%	I_{DD2} = 0 to max.
Output voltage temperature coefficient	$(\Delta V_{DD2}/V_{DD2})/\Delta T$		0.017 0.03		%/°C	I_{DD2} = 10 mA I_{DD2} = 50 mA
Capacitive load	C_{DD2}			1000	µF	
Output voltage ripple	$V_{DD2RIPPLE}$		1	5	$mV_{P\text{-}P}$	20 MHz bandwidth; I_{DD2} = max.
			1			1 kHz bandwidth; I_{DD2} = max.
Start-up current	$I_{DD1\text{-}SU}$		600	750	mA	700 ns max.
Start-up time	t_{SU}		200		µs	No load
			400			Full load (resistive)
Convertor frequency	f_{OSC}	105	113	120	MHz	

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Thermal Specifications

Parameter		Symbol	Min.	Typ.	Max.	Units	Test Conditions
Junction-to-ambient thermal resistance	ILDC1x-15E	θ_{JA}		46		°C/W	2s2p PCB per JESD51; leadframe pad grounded (if applicable); free air.
	ILDC1xVE			46			
Junction-to-case (top) thermal resistance	ILDC1x-15E	θ_{JC}		12			
	ILDC1xVE			9			
Junction-to-ambient thermal resistance	ILDC1x-15E	θ_{JA}		52.5			2-sided PCB with 2 oz Cu and thermal vias; leadframe pad grounded.
	ILDC1xVE			67			
Junction-to-case (top) thermal resistance	ILDC1x-15E	θ_{JC}		8			
	ILDC1xVE			12			
Package power dissipation	ILDC1x-15E	P			1.5	W	
	ILDC1xVE				1.5		

Isolation Specifications

Parameter		Symbol	Min.	Typ.	Max.	Units	Test Conditions
Isolation voltage*	ILDC1x-15E	V_{ISO}	2.5			kV_{RMS}	Per VDE V 0884-11
	ILDC1xVE		5				
Transient overvoltage	ILDC1x-15E	V_{IOTM}	4			kV_{PK}	
	ILDC1xVE		6				
Surge immunity	ILDC1x-15E		6.4			kV_{PK}	
	ILDC1xVE		12.8				
Creepage distance (external)	ILDC1x-15E		3.5			mm	Per IEC 60601
	ILDC1xVE		8.03	8.3			
Comparative tracking index	ILDC1x-15E	CTI	≥175			V_{RMS}	Per IEC 60112
	ILDC1xVE		≥600				
Total barrier thickness (internal)			0.012	0.016		mm	
Isolation barrier resistance		R_{IO}		$>10^{14}$		Ω	500 V_{RMS}
Isolation barrier capacitance		C_{IO}		7		pF	f = 1 MHz
Leakage current				0.2		μA_{RMS}	240 V_{RMS}, 60 Hz
Barrier life				44000		Years	100°C, 1000 V_{RMS}, 60% CL activation energy

UL 1577 approval pending under Component Recognition Program File Number E207481.

*ILDC1x-15E tested at 3 kV_{RMS} (4.24 V_{PK}) for 1 second, 5 pC partial discharge limit in accordance with VDE 0884 Method B1 and IEC60747-17.
Each lot sample tested at 2.5 kV_{RMS} (3.53 V_{PK}) for 1 minute.

ILDC1xVE tested at 6 kV_{RMS} (8.5 kV_{PK}) for 1 second, 5 pC partial discharge limit in accordance with VDE 0884 Method B1 and IEC60747-17.
Each lot sample tested at 5 kV_{RMS}
(7.07 kV_{PK}) for 1 minute.

Features

Best-in-Class Isolation

A unique ceramic/polymer composite barrier provides virtually unlimited barrier life. The DFN versions provide full 2.5 kV_{RMS} isolation, and the wide-body SOIC version provides a remarkable 5 kV_{RMS} and true eight-millimeter creepage in accordance with IEC60601.

Low Parts Count

The only external components required are three inexpensive bypass capacitors on the VDD1, VDD2, and VF pads. This low external parts count reduces board area and cost.

Fully Regulated with no Minimum Load

Unlike other DC-DC convertors, ILDC1x devices have fully-regulated outputs specified over the full input voltage and output current operating ranges. This eliminates the need for an external regulator or load resistor.

Ultralow Ripple

An inexpensive external filter capacitor (VF) and excellent line regulation and ensures the output ripple voltage is less than 5 mV_{P-P}.

Short-Circuit Protection

The output current is internally limited to approximately 125 mA. This provides short-circuit protection and eliminates the need for external protection circuitry.

Inherently Low EMI

The DC-DC convertor oscillator operates above 88 MHz, a much higher frequency than conventional DC-DC convertors, where emission limits are higher since there is less risk of interference with some common commercial radio and television broadcasting.

Frequency-hopping technology dramatically reduces peak EMI, and synchronous rectification and PWM control are avoided, resulting in inherently low EMI. Ferrite beads are not required for EMI mitigation.

This inherently low EMI allows CISPR and FCC compliance without external components or shielding.

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Operation

An ILDC1x block diagram is shown below:

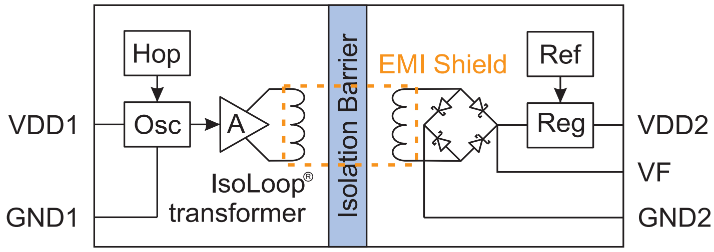

Figure 1. ILDC1x detailed block diagram.

A 113 MHz oscillator drives a high-frequency power amplifier, which in turn drives an IsoLoop® microtransformer primary. Frequency hopping reduces EMI peak amplitudes, and embedded magnetic shielding further reduces radiated EMI.

On the other side of the isolation barrier, the transformer secondary output is filtered, rectified, and regulated by a low-EMI low drop-out regulator with a precision bandgap voltage reference.

A high-temperature process allows up to 175 °C junction temperature for full power up to 125 °C operating temperature with no derating.

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Application Information

Low Parts Count

The only external components required are three inexpensive bypass capacitors: a 0.1 µF ceramic capacitor placed as close as possible to the VDD1 pad, a 10 µF ceramic capacitor for the VDD2 pad, and a 0.1 µF/16 V filter capacitor near the VF pad.

Start-Up Current

The input power supply to the DC-DC convertor must be able to supply a start-up surge current of 750 mA for at least 700 ns for the DC-DC convertor to start up properly. If the input current is supplied by a regulator (such as shown in Figure 16) a one-amp regulator provides adequate current.

Fully Regulated with no Minimum Load

The ILDC1x has a fully-regulated output specified over the full input voltage and output current operating ranges, eliminating the need for an external regulator or load resistor.

Optional External Regulation

An external regulator can be used in place of the ILDC1x's internal low drop-out regulator for voltages up to approximately 7.5 volts. The maximum output current decreases at higher regulator output voltages, but the output power capacity remains approximately 250 milliwatts.

Inherently Low EMI

Inherently low EMI eliminates the need for ferrite beads or other EMI mitigation.

No Temperature Derating

A double sided, double buried power plane ("2s2p") printed-circuit board optimizes thermal performance, allowing full power up to 125 °C operating temperature with no derating. Thermal vias should be used between the power plane and the board surfaces. Both input-side ground pads and the leadframe pad (for the DFN package) should be grounded using wide traces to help cool the leadframe.

At the full output current with the recommended PCB, the ILDC1x dissipates approximately one watt and the resultant junction temperature rise is 46 °C for either package, so at 125 °C ambient the junction temperature is less than the 175 °C maximum junction temperature.

A simple double-sided PCB with thermal vias can be used rather than a 2s2p PCB with some derating (see Figure 6).

Maintaining Creepage

Creepage distances are often critical in isolated circuits. Therefore power planes should be spaced to avoid compromising creepage or clearance, and board pads should not extend past the part pads to avoid compromising clearance.

Typical Performance Graphs

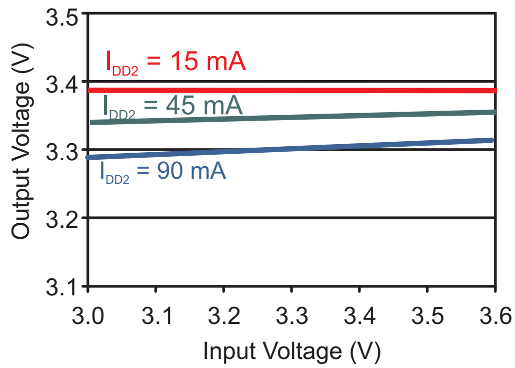

Figure 2. Typical line regulation (ILDC11).

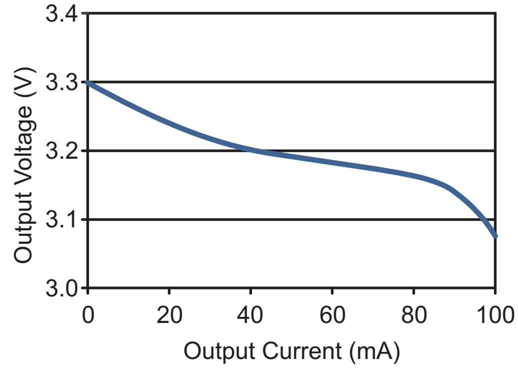

Figure 3. Typical load regulation (ILDC11).

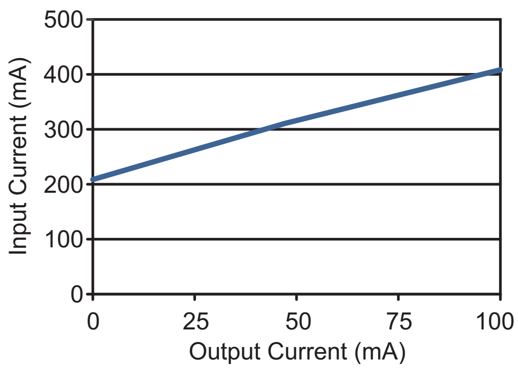

Figure 4. Typical input current versus output current (ILDC11).

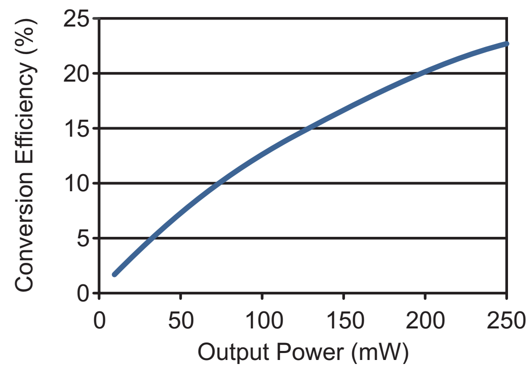

Figure 5. Conversion power efficiency (ILDC11).

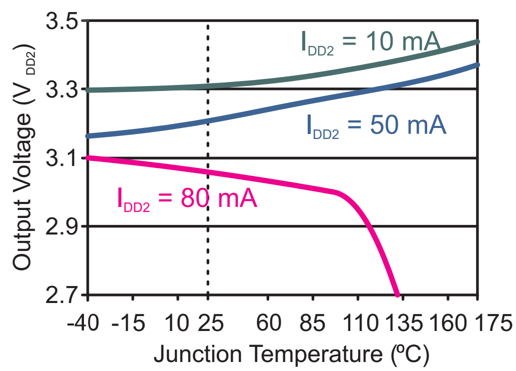

Figure 6. DC-DC convertor output vs. temperature and self-limiting current (ILDC11)

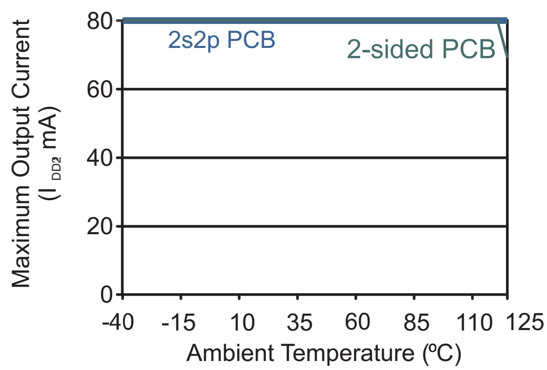

Figure 7. Temperature derating curve (ILDC11).

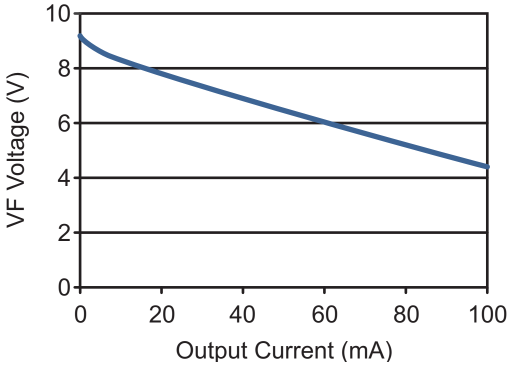

Figure 8. Typical unregulated voltage (VF) versus output current. (V_{DD1} = 3.3 V; 25 °C).

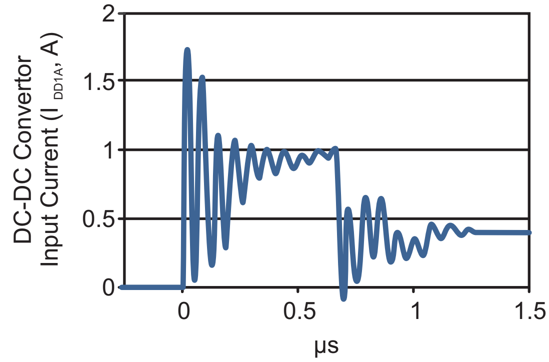

Figure 9. Typical start-up current (max. load; no V_{DD1} bypass capacitor).

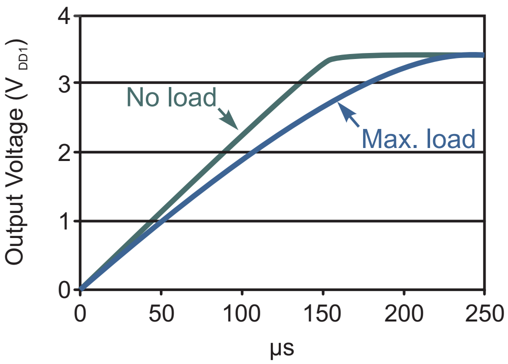

Figure 10. Typical output startup (ILDC11; C_L = 10 µF).

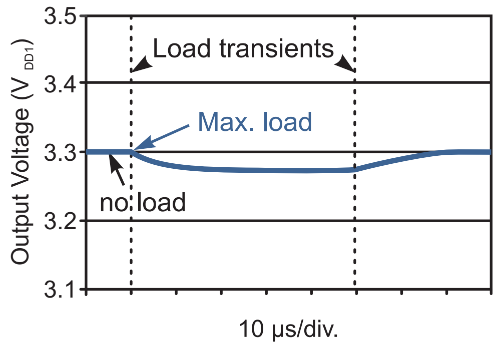

Figure 11. Typical output transient load response (ILDC11; C_L = 10 µF).

Typical Applications

Typical isolated RS-485 bus power supply and node:

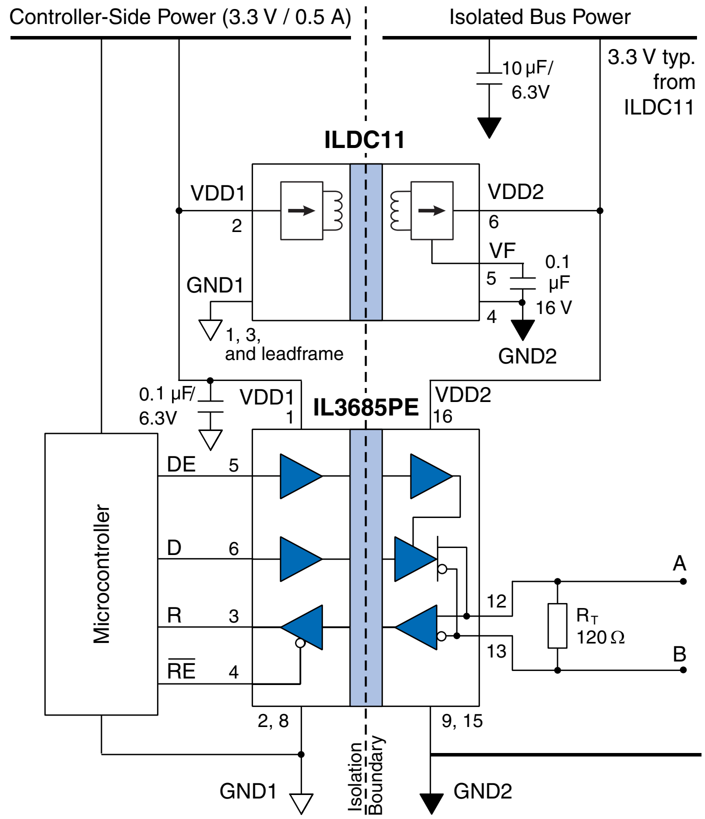

Figure 12. An isolated 3.3-volt RS-485 bus supply and node.

An isolated 3.3 volt bus supply is generated from the controller supply. The ILDC11 generates enough power for an RS-485 bus and termination resistors.

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Isolated controller supply from a 3.3-volt bus:

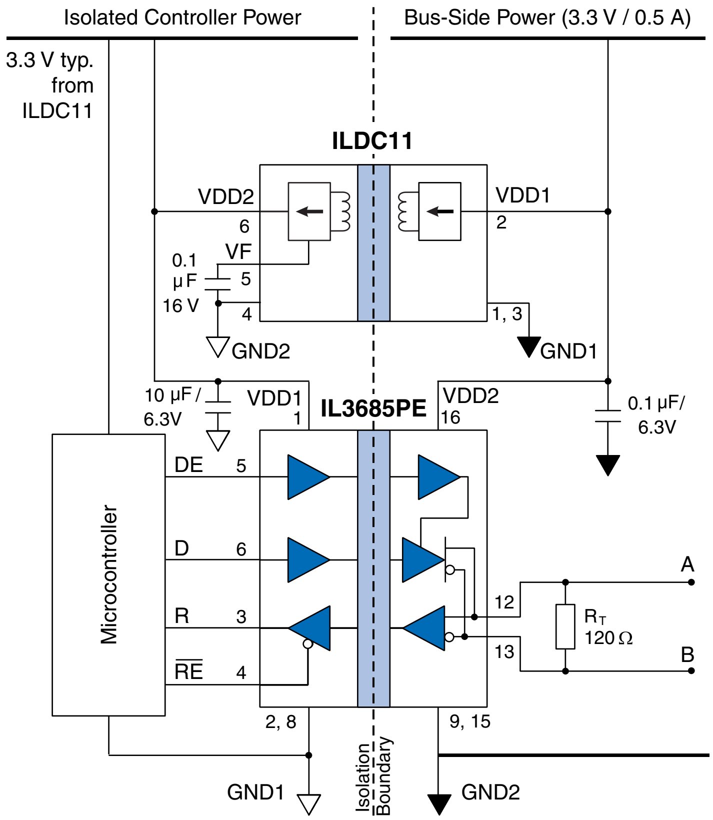

Figure 13. Reversed configuration: isolated controller supply from a 3.3-volt bus.

Normally the bus supply is generated from the controller supply, but the reverse is also possible. An advantage of this configuration is that since the DC-DC convertor does not need to supply the bus-side power, the bus can have two 120Ω termination resistors with the transceiver running at maximum speed, a combination that would exceed the ILDC11's maximum output current if it were powering the bus. The ILDC11 generates enough power to supply a microcontroller and other circuitry in addition to a transceiver.

Isolated SPI sensor interface:

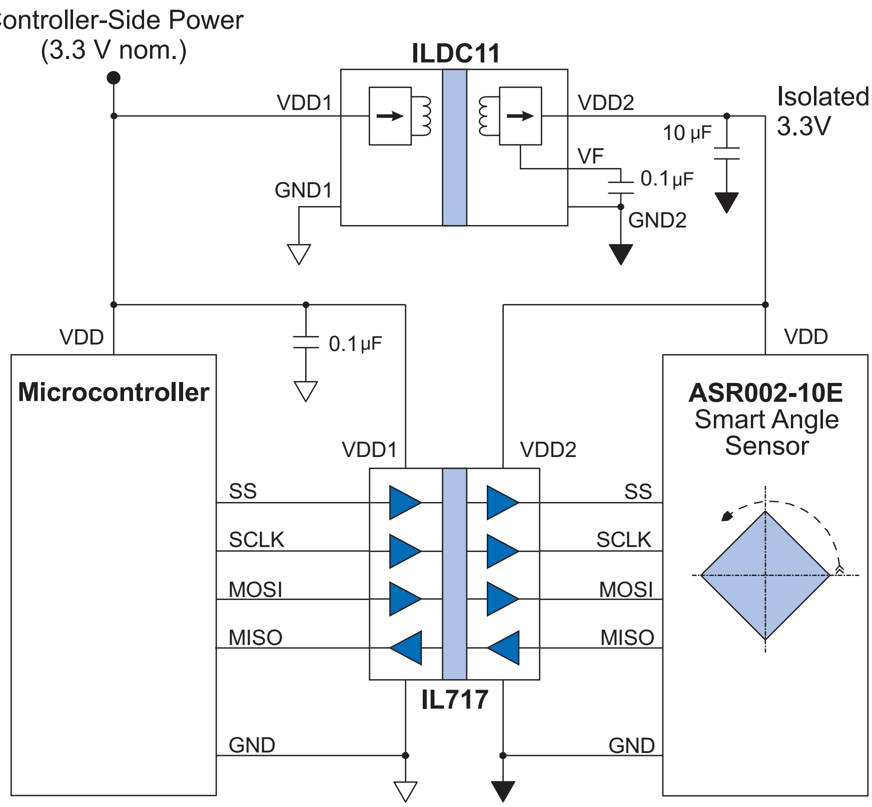

Figure 14. An isolated SPI sensor interface.

Isolation reduces noise by eliminating ground loops, and improves safety by providing another insulation level. The ILDC11 generates an isolated power supply to independently power the sensor. The four-channel IL717 isolator transmits the SPI signals while maintaining galvanic isolation. A five-channel IL261 isolator can be used to select between two sensors A similar circuit can be used for a variety of four-wire interface sensors, including angle, magnetic field, current, temperature, or pressure sensors.

Isolated SPI / MICROWIRE ADC interface:

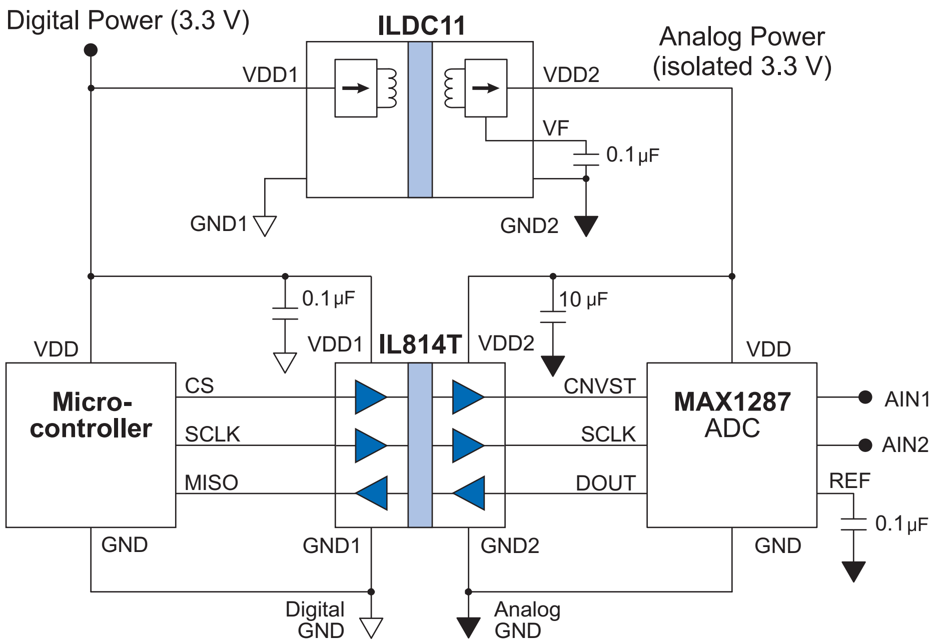

Figure 15. Isolated ADC serial interface.

An isolated analog power supply generated by the ILDC11 significantly improves the noise performance of a successive-approximation ADC. The three-channel IL814TE isolates the ADC's serial interface. A similar circuit can be used for other three-wire SPI or MICROWIRE peripherals such as DACs or sensors.

External regulator for nonstandard voltages:

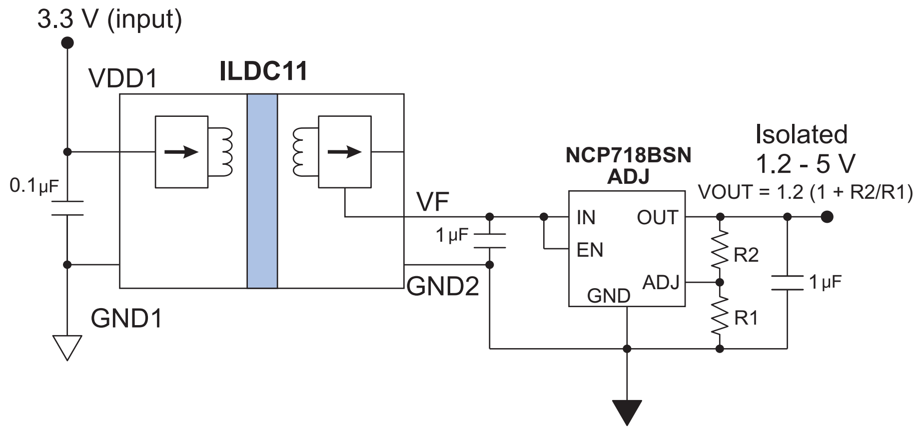

Figure 16. A 3.3-volt input / adjustable output isolated supply using an external regulator.

An inexpensive adjustable low-dropout regulator can be added to the ILDC11's VF output to provide nonstandard output voltages.

5-volt input:

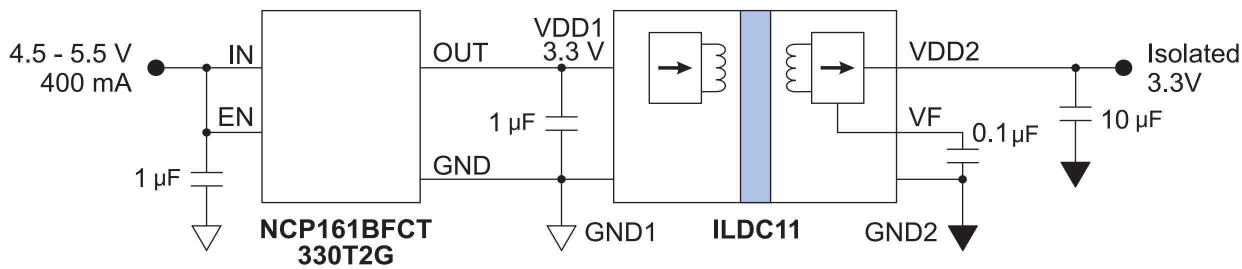

Figure 17. A 5-volt input / 3.3-volt output isolated supply.

An inexpensive chip-scale linear regulator such as an NCP161 can be used for a 5-volt input.

High-efficiency 5-volt input:

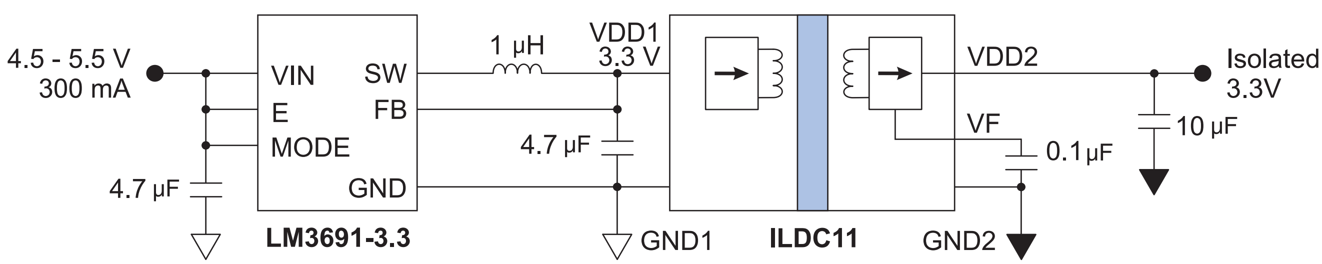

Figure 18. A 5-volt input / 3.3-volt with a buck regulator.

A step-down (buck) switching regulator can be used with a 5-volt input for higher efficiency than a linear regulator.

Isolated 12-volt output:

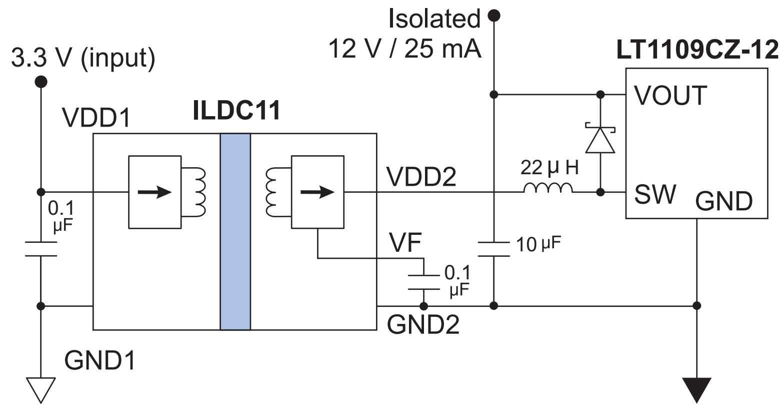

Figure 19. A 3.3-volt input / 12-volt output isolated supply.

An inexpensive boost regulator can be added to an ILDC1x to provide an isolated 12-volt output. The ILDC1x's inherent stability allows it to directly drive the inductive load required for the boost regulator.

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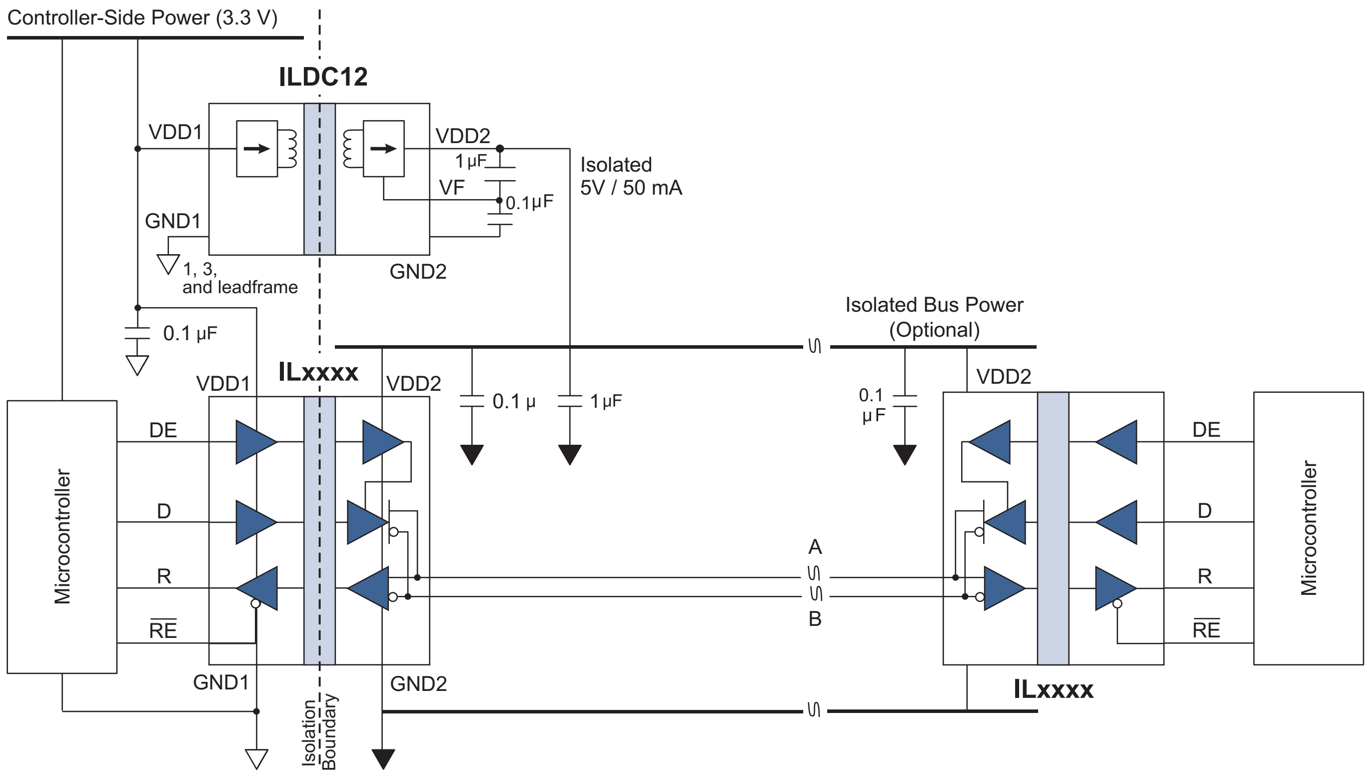
Isolated 5-volt bus system:



5-Volt Isolated Transceivers							
Model	**Duplex**	**Inputs**	**Mbps**	**Nodes**	**Bus ESD**	**Key Features**	**Available Packages**
IL3022	Full	Digital	4	32	7.5 kV	Low Cost	0.3" SOIC16
IL2985	Half	Digital	4	32	15 kV	Low Power	0.3" SOIC16
IL3085	Half	Digital	4	32	15 kV	Low Cost	QSOP16; 0.15" SOIC16; 0.3" SOIC16
IL3522	Full	Digital	40	50	15 kV	Very High Speed	0.3" SOIC16
IL3585	Half	Digital	40	50	15 kV	Very High Speed	0.15" SOIC16; 0.3" SOIC16
IL3685	Half	Digital	40	50	15 kV	PROFIBUS	QSOP16; 0.15" SOIC16; 0.3" SOIC16

Figure 20. An isolated 5-volt RS-485 bus system.

An ILDC12 provides isolated five volts for a traditional RS-485 bus. The ILDC12's output capacity is 50 mA, which is enough to power an RS-485 transceiver without termination resistors. It can also power a number of additional low-power nodes if desired. Low-power IL2985 transceivers have a maximum bus-side quiescent supply current of less than 2 mA. Other 5-volt isolated transceiver options include the 40 Mbps IL3585, the 40 Mbps PROFIBUS IL3685, the low-cost IL3085, and the full-duplex IL3522 or IL3022. Ultraminiature IL3685-1E or IL3085-1E QSOP16 versions are available to minimize board area.

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Isolated H-Bridge Drivers:

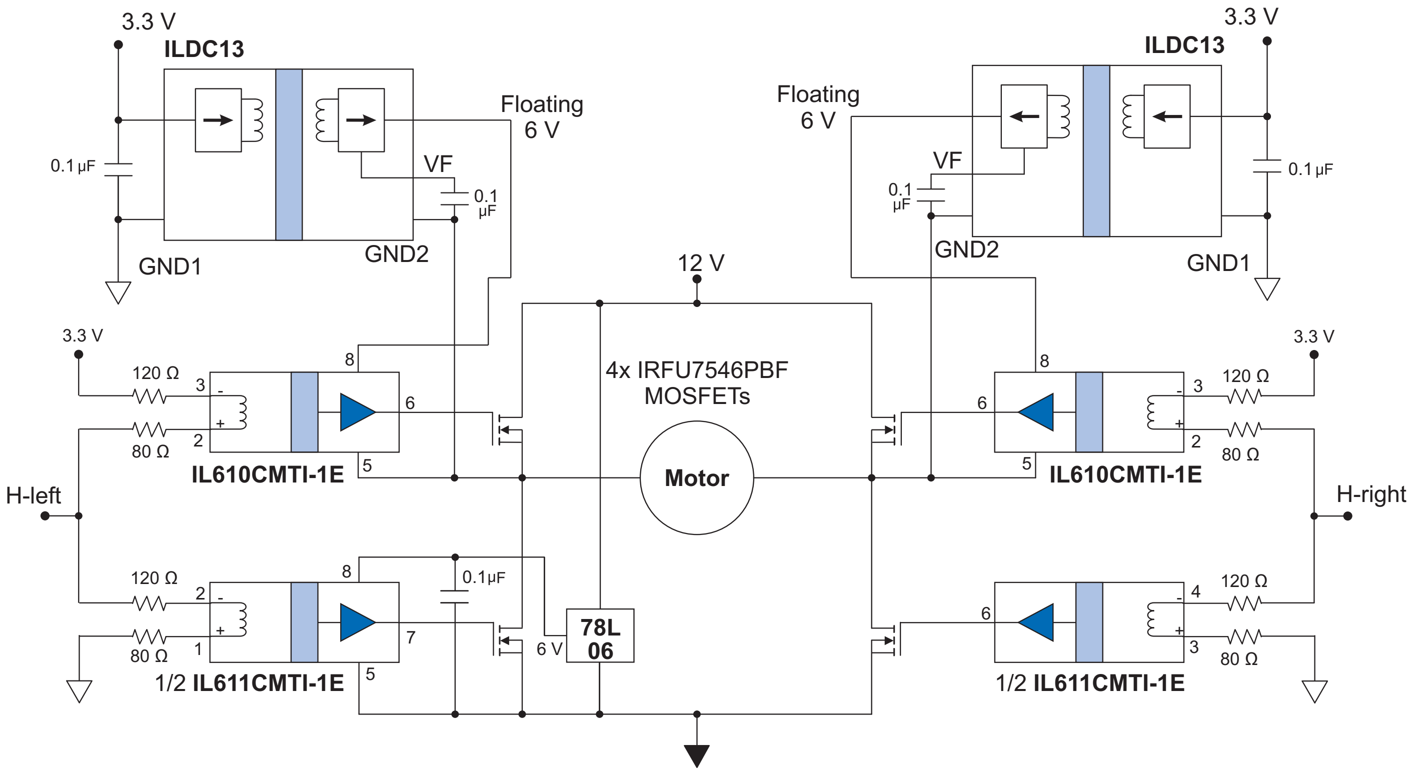

Figure 21a. Isolated H-Bridge Driver for 6 V gate drive.

The ILDC13 isolates and floats the high-side gate power, and commodity regulators provide the six volts needed to power the isolators and drive the MOSFET gates.

Four channels of isolation in three MSOP-8 isolators allow referencing the high-side gate signals to the floating MOSFET source pins, plus they level-shift low-voltage controller outputs to six volts to drive MOSFET gates. These isolators have low-impedance outputs to directly drive MOSFETs, so separate MOSFET drivers are not required. The IL600CMTI isolators are the world's smallest isolators, with the highest common-mode transient immunity in the industry. With up to 350 kV/µs guaranteed transient immunity, the IL610CMTIs prevent spurious isolator switching when the high-side MOSFETs switch.

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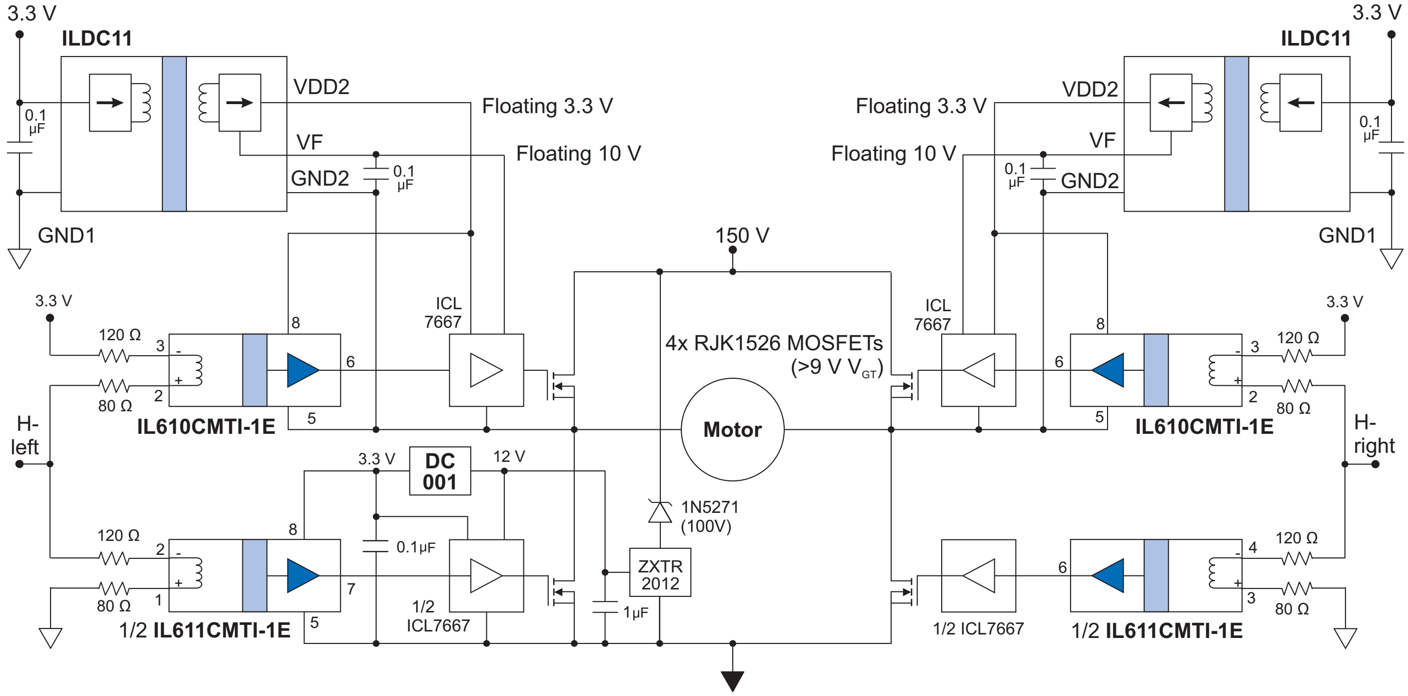

Figure 21b. Isolated H-Bridge Driver for 12 V gate drive.

An ILDC1x's unregulated VF output can be used to drive MOSFETs requiring approximately 12 volts of gate drive. The VF output provides a minimum of nine volts, which is enough to fully saturate RJK1526 or similar MOSFETs. ICL7667 or similar MOSFET drivers translate the 3.3 V IL611CMTI isolator outputs to 12 volts and provide instantaneous high gate-drive currents for fast switching speeds with large MOSFETs.

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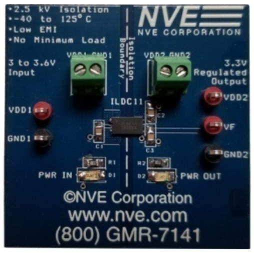
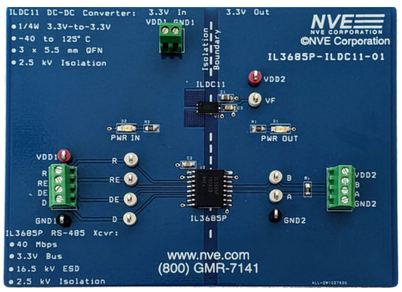
Evaluation Boards



ILDC11-01 Evaluation Board
This board uses a 2s2p PCB with thermal vias for optimal thermal performance.
The 1.75 by 1.75 inch (45 by 45 mm) board has an ILDC11-15E plus the three required external bypass capacitors as well as LEDs to show the DC-DC convertor is operating. Screw terminals provide easy connections.



***IL3685P-ILDC11-01*: Isolated 3.3 V RS-485 Node**
The ILDC11 is ideal for generating isolated bus supplies for RS-485 nodes. This 4 x 3 inch (100 x 75 mm) board demonstrates a complete isolated RS-485 node using an IL3685PE 40 Mbps isolated transceiver and an ILDC11-15E DC-DC convertor.

The board demonstrates recommended layout practices, and provides screw terminal and test point connections.

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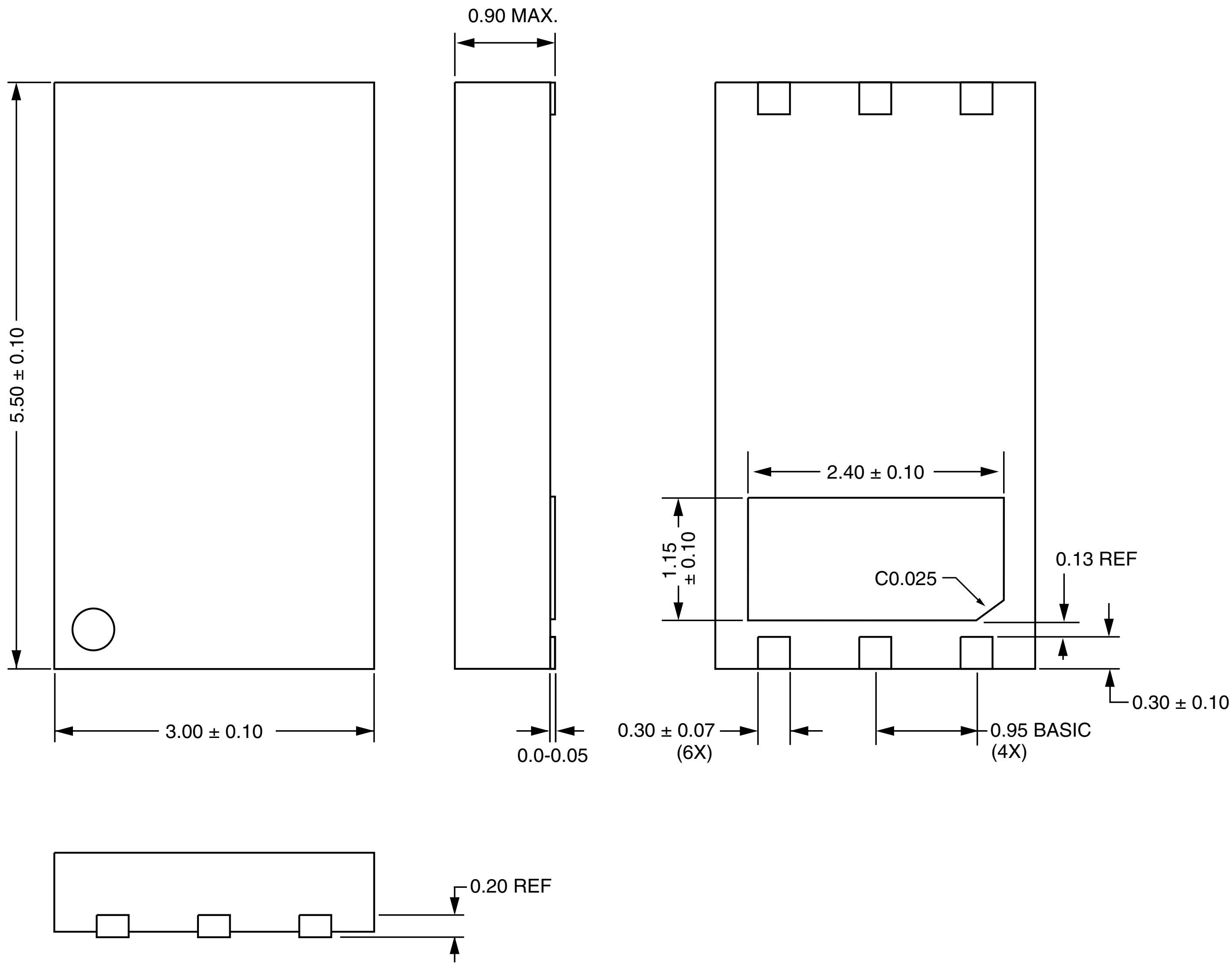
ILDC1x-15E (3 mm x 5.5 mm DFN6 Package)



Pad	Symbol	Description
1	GND1	Input-Side Ground (internally connected to pad 3)
2	VDD1	Input Supply (bypass with a 0.1 μF capacitor)
3	GND1	Input-Side Ground (internally connected to pad 1)
4	GND2	Output-Side Ground
5	VF	Filter capacitor / external regulator (connect to a 0.1 μF / 16 V external capacitor; can be used with optional external regulator for voltages other than 3.3V)
6	VDD2	Output (bypass with a 10 μF / 6.3 V capacitor)
Leadframe pad	GND1	Input-side leadframe connection (connect to GND1 to optimize thermal performance)

Notes:
- Dimensions in millimeters.
- Soldering profile per JEDEC J-STD-020C, MSL 1.

RoHS COMPLIANT

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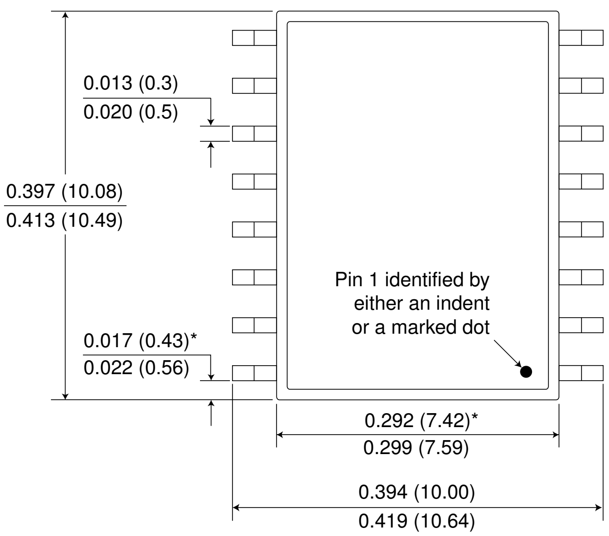
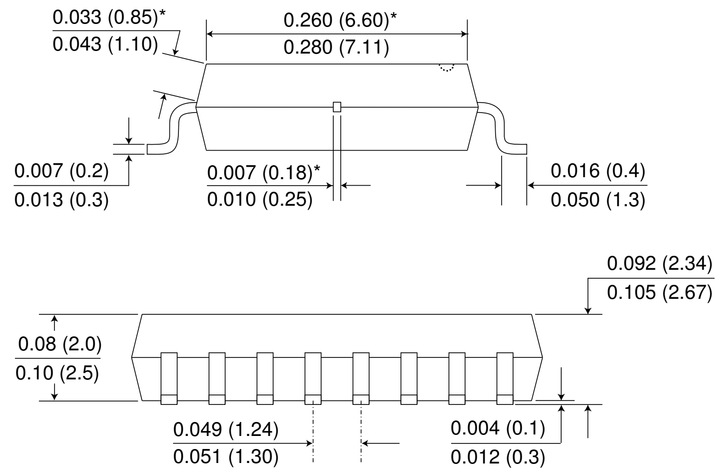
ILDC1xVE (SOIC16 Wide-Body Package)

Dimensions in inches (mm); scale = approx. 5X



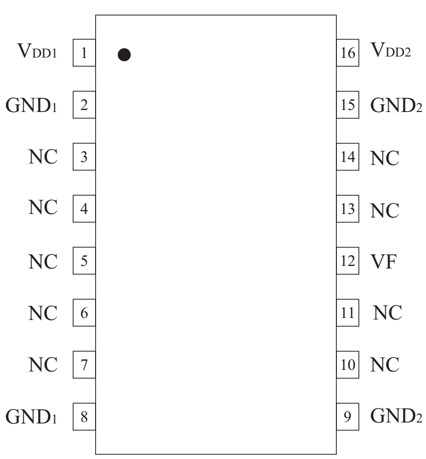


NOTE: Pin spacing is a BASIC dimension; tolerances do not accumulate

*Specified for True 8™ package to guarantee 8 mm creepage per IEC 60601.

Soldering profile per JEDEC J-STD-020C, MSL 1.

RoHS COMPLIANT



Pin	Symbol	Description
1	VDD1	Input Supply (bypass with a 0.1 µF capacitor)
2	GND1	Input-Side Ground (internally connected to pin 8)
8	GND1	Input-Side Ground (internally connected to pin 2)
9	GND2	Output-Side Ground (internally connected to pin 15)
12	VF	Filter capacitor / external regulator (connect to a 0.1 µF / 16 V external capacitor; can be used with optional external regulator for voltages other than 3.3V)
16	VDD2	Output (bypass with a 10 µF / 6.3 V capacitor)
3, 4, 5, 6, 7, 10, 11, 13, 14	NC	No internal connection

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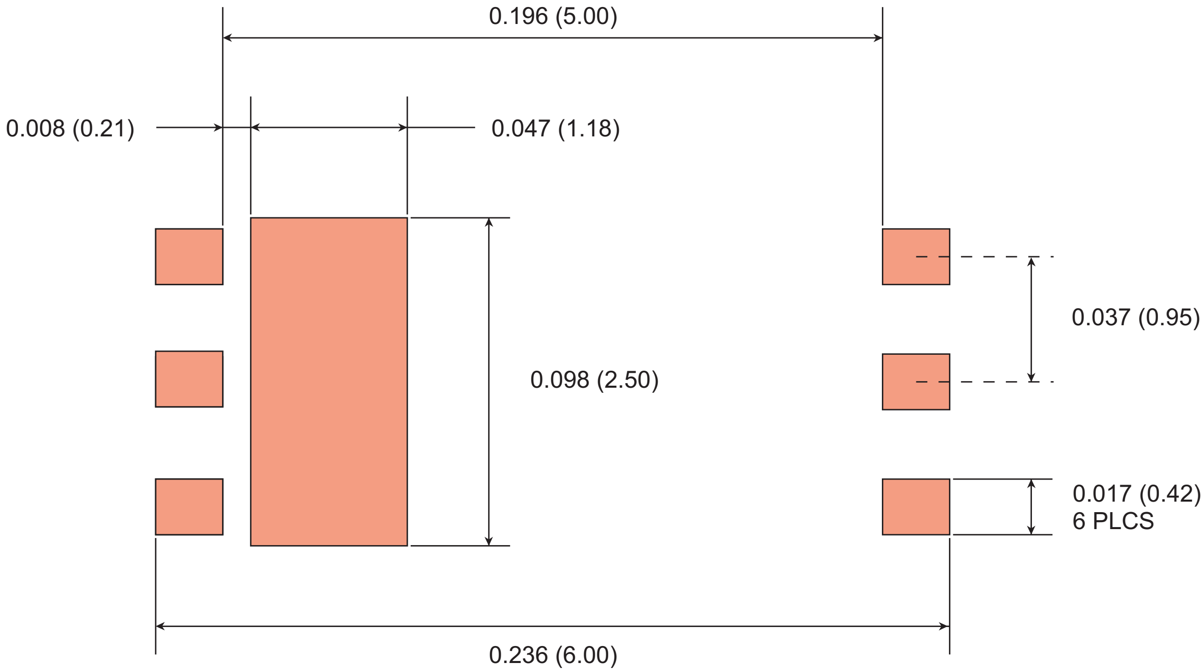
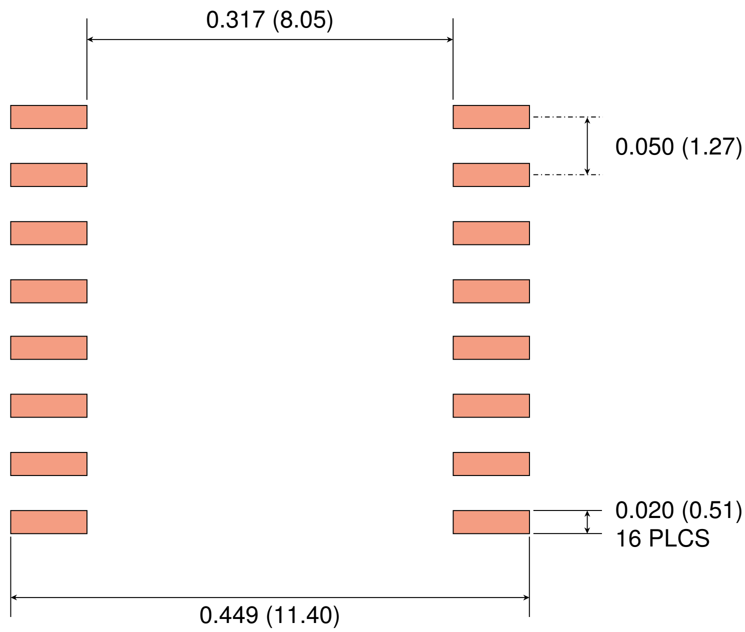
ILDC1x-15E Recommended Layout Footprint



ILDC1xVE Recommended Layout Footprint



Dimensions in inches (millimeters)

Ordering Information

ILDC1x-15E TR7

Product Line
IL = Isolation products

Product Family
DC = DC-DC convertor

Part Numbers
11 = 3.3 V in / 3.3 V out
12 = 3.3 V in / 5 V out
13 = 3.3 V in / 6 V out

Part Package
15 = 3 x 5.5 mm DFN package
V = SOIC16 high-voltage wide-body package

RoHS-compliance
E = RoHS-compliant

Bulk Packaging
Blank = Bulk (tubes)
TR7 = 7" Tape and Reel
TR13 = 13" Tape and Reel

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Revision History

ISB-DS-001-ILDC1x-RevF
April 2021

Changes
- Added 5 V and 6 V output options (ILDC12 and ILDC13).
- Added a wide-body SOIC16 version with 5 kV_{RMS} isolation (ILDC1xVE).
- Updated isolation specifications (p. 3).
- Discontinued the 5 V bus demo board with an external regulator since we now offer a 5 V output DC-DC convertor version.

ISB-DS-001-ILDC11-RevE
Oct. 2020

Changes
- Added VF vs. output current typical performance graph (Figure 8).
- Added descriptions of external regulator options.
- Revised external regulator reference designs and isolated H-bridge driver.

ISB-DS-001-ILDC11-RevD
Sept. 2020

Change
- More detailed Figure 18 (isolated H-bridge driver).

ISB-DS-001-ILDC11-RevC
July 2020

Changes
- Added start-up current specification (p. 2) and typical graph (Figure 10).
- Added thermal protection description (p. 2) and typical graph (Figure 10).
- Updated step-down regulator reference design with higher-current regulator (Figure 16).

ISB-DS-001-ILDC11-RevB
June 2020

Change
- Added efficiency performance graph (Figure 5).

ISB-DS-001-ILDC11-RevA
June 2020

Changes
- Finalized performance graphs.
- Changed package description from QFN to DFN.
- Additional application circuits.
- Initial release.

ISB-DS-001-ILDC11-PRELIM3
February 2020

Changes
- Updated and expanded thermal resistance specifications.
- Added a derating curve for a double-sided PCB.
- Added application circuits.
- Added Evaluation Boards.

ISB-DS-001-ILDC11-PRELIM2
January 2020

Changes
- Updated and expanded thermal resistance specifications.
- Added application circuits with external regulators.
- Added recommended pad footprint layout (p. 12).

ISB-DS-001-ILDC11-PRELIM
December 2019

Change
- Preliminary release.

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ISB-DS-001-ILDC1x

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