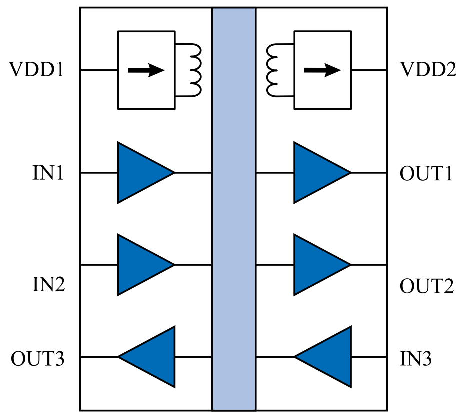
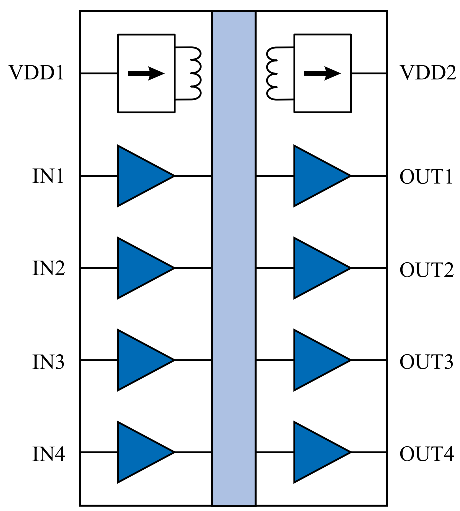
High-Speed Data Couplers with Integrated DC-DC Convertors

Block Diagrams



IL7614



IL7615

Features

- 110 Mbps
- Integrated ¼ watt, 3.3-to-3.3 V DC-DC convertor
- 6 kV_{RMS} Reinforced Isolation
- Thermal shutdown protection
- −40 °C to 125 °C temperature range
- UL1577 and VDE V 0884-11 pending
- 0.3" True 8™ mm 16-pin SOIC package

Applications

- Industrial automation
- IEC 60601 medical devices
- Grid infrastructure
- Test and measurement
- Three-wire SPI

Description

The IL76xx-Series are high-speed, fully-isolated, data couplers with integrated 3.3-to-3.3 V, one-quarter watt DC-DC convertors. This level of integration dramatically reduces chip count and board area.

The devices use NVE's proven, patented* spintronic Giant Magnetoresistance (GMR) isolation technology and IsoLoop® high-efficiency micro-scale isolation transformers.

Frequency hopping and shielding minimize EMI.

A unique ceramic/polymer composite barrier provides best-in-class isolation and virtually unlimited barrier life.

IsoLoop® is a registered trademark of NVE Corporation.
*U.S. Patent number 5,831,426; 6,300,617 and others.

PREVIEW

Absolute Maximum Ratings[1]

Parameter	Symbol	Min.	Typ.	Max.	Units	Test Conditions
Storage temperature	T_S	–55		175	°C	
Junction temperature	T_J	–55		175	°C	
Supply voltage	V_{DD1}	–0.5		6	V	
Digital input voltage		–0.5		V_{DD} + 0.5	V	
Digital output voltage		–0.5		V_{DD} + 1	V	
Coupler output current drive	Io			10	mA	
Lead solder temperature				260	°C	10 sec.
ESD			2		kV	HBM

Recommended Operating Conditions

Parameter	Symbol	Min.	Typ.	Max.	Units	Test Conditions
Input-side supply voltage	V_{DD1}	3	3.3	3.6	V	
Ambient operating temperature	T_{min}; T_{max}	–40		125	°C	
Junction temperature	T_J	–40		150	°C	
High-level digital input voltage	V_{IH}	2.4		V_{DD1}	V	V_{DD1} = 3.3 V
Low-level digital input voltage	V_{IL}	0		0.8	V	

Safety and Approvals

VDE V 0884-11 (pending)

V-Series (Reinforced Isolation; VDE File Number 5016933-4880-0002)

- Working Voltage (V_{IORM}) 1000 V_{RMS} (1415 V_{PK}); reinforced insulation; pollution degree 2
- Isolation voltage (V_{ISO}) 6000 V_{RMS}
- Surge immunity (V_{IOSM}) 12.8 kV_{PK}
- Surge rating 8 kV
- Transient overvoltage (V_{IOTM}) 6000 V_{PK}
- Each part tested at 2387 V_{PK} for 1 second, 5 pC partial discharge limit
- Samples tested at 6000 V_{PK} for 60 sec.; then 2122 V_{PK} for 10 sec. with 5 pC partial discharge limit

Safety-Limiting Values	Symbol	Value	Units
Safety rating ambient temperature	T_S	180	°C
Safety rating power (180°C)	P_S	270	mW
Supply current safety rating (total of supplies)	I_S	54	mA

UL 1577 (Component Recognition Program File Number E207481)

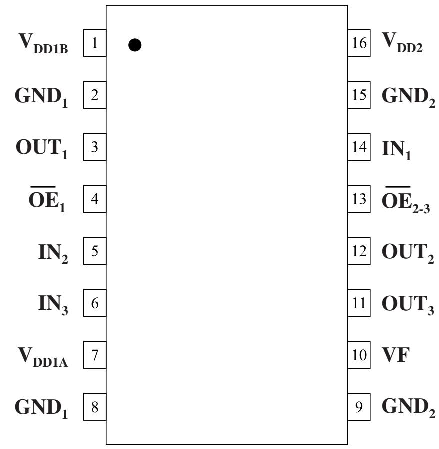
- V-Series parts tested at 7.2 kV_{RMS} (10.2 kV_{PK}) for 1 second; each lot sample tested at 6 kV_{RMS} (8485 V_{PK}) for 1 minute

Soldering Profile

Per JEDEC J-STD-020C, MSL 1

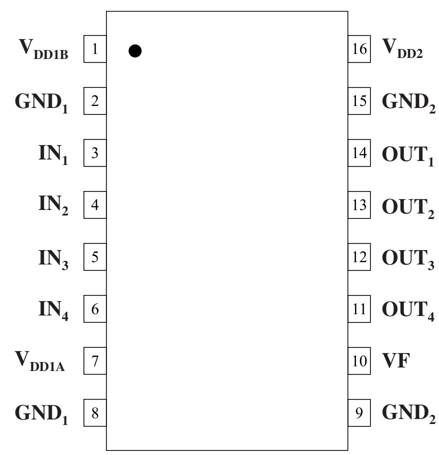
IL7614V Pin Connections

1	V_{DD1B}	Coupler controller-side power supply input (3.3 V nominal).
2	GND_1	Ground return for V_{DD1} (pins 2 and 8 internally connected)
3	OUT_1	Data out, channel 1
4	$\overline{OE}_1$	Channel 1 output enable (if high, OUT_1 = high impedance; has a 500 kΩ nominal internal pulldown)
5	IN_2	Data in, channel 2
6	IN_3	Data in, channel 3
7	V_{DD1A}	DC-DC convertor input voltage (3.3 V nominal); bypass with 0.1 µF.
8	GND_1	Ground return for V_{DD1} (pins 2 and 8 internally connected)
9	GND_2	Ground return for V_{DD2} (pins 9 and 15 internally connected)
10	VF	Output-side rectifier output / regulator input; connect to a 0.1 µF/16 V external filter capacitor.
11	OUT_3	Data out, channel 3
12	OUT_2	Data out, channel 2
13	$\overline{OE}_{2\text{-}3}$	Channel 2 and 3 output enable (if high, OUT_2 and OUT_3 are high impedance; has a 500 kΩ nominal internal pulldown)
14	IN_1	Data in, channel 1
15	GND_2	Ground return for V_{DD2} (pins 9 and 15 internally connected)
16	V_{DD2}	Isolated supply voltage



IL7615V Pin Connections

1	V_{DD1B}	Coupler controller-side power supply input (3.3 V nominal).
2	GND_1	Ground return for V_{DD1} (pins 2 and 8 internally connected).
3	IN_1	Data in, channel 1
4	IN_2	Data in, channel 2
5	IN_3	Data in, channel 3
6	IN_4	Data in, channel 4
7	V_{DD1A}	DC-DC convertor input voltage (3.3 V nominal); bypass with 0.1 µF.
8	GND_1	Ground return for V_{DD1} (pins 2 and 8 internally connected).
9	GND_2	Ground return for V_{DD2} (pins 9 and 15 internally connected).
10	VF	Output-side rectifier output / regulator input; connect to a 0.1 µF/16 V external filter capacitor.
11	OUT_4	Data out, channel 4
12	OUT_3	Data out, channel 3
13	OUT_2	Data out, channel 2
14	OUT_1	Data out, channel 1
15	GND_2	Ground return for V_{DD2} (pins 9 and 15 internally connected).
16	V_{DD2}	Isolated supply voltage



Coupler Specifications (V_{DD} = 3.3 V; T_{min} to T_{max} unless otherwise stated)

Electrical Specifications						
Parameters	**Symbol**	**Min.**	**Typ.**	**Max.**	**Units**	**Test Conditions**
Controller-side coupler quiescent supply current						
IL7614V	I_{DD1B}		1.2	1.75	mA	
IL7615V			0.3	0.4		
Isolated-side quiescent supply current						
IL7614V	I_{DD2}		2.4	3.5	mA	
IL7615V			4.8	7		
Controller-side dynamic supply current						
IL7614V	I_{DD1B}		0.3	0.5	mA/Mbps	All channels
IL7615V			0.6	1		
Isolated-side dynamic supply current						
IL7614V	I_{DD2}		0.15	0.25	mA/Mbps	
IL7615V			0			
Logic input current	I_I	−10		10	μA	
Logic high output voltage	V_{OH}	V_{DD} – 0.1	V_{DD}		V	I_O = −20 μA, V_I = V_{IH}
		0.8 x V_{DD}	0.9 x V_{DD}			I_O = −4 mA, V_I = V_{IH}
Logic low output voltage	V_{OL}		0	0.1	V	I_O = 20 μA, V_I = V_{IL}
			0.5	0.8		I_O = 4 mA, V_I = V_{IL}

Coupler Switching Specifications						
Maximum data rate		100	110		Mbps	C_L = 15 pF
Pulse width[6]	PW	10			ns	50% Points, V_O
Propagation delay input to output (high to low)	t_{PHL}		12	18	ns	C_L = 15 pF
Propagation delay input to output (low to high)	t_{PLH}		12	18	ns	C_L = 15 pF
Pulse width distortion[2]	PWD		2	3	ns	C_L = 15 pF
Propagation delay skew[3]	t_{PSK}		4	6	ns	C_L = 15 pF
Output rise time (10%–90%)	t_R		2	4	ns	C_L = 15 pF
Output fall time (10%–90%)	t_F		2	4	ns	C_L = 15 pF
Common mode transient immunity (output logic high or logic low)[4]	$\|CM_H\|,\|CM_L\|$	30	50		kV/μs	V_{CM} = 1500 V_{DC} $t_{TRANSIENT}$ = 25 ns
Channel-to-channel skew	t_{CSK}		2	3	ns	C_L = 15 pF
Dynamic power consumption			140	240	μA/Mbps	per channel

Coupler Magnetic Field Immunity[7]						
Power frequency magnetic immunity	H_{PF}	1000	1500		A/m	50Hz/60Hz
Pulse magnetic field immunity	H_{PM}	1800	2000		A/m	t_p = 8μs
Damped oscillatory magnetic field	H_{OSC}	1800	2000		A/m	0.1Hz – 1MHz
Cross-axis immunity multiplier[8]	K_X		2.5			

DC-DC Convertor Specifications

T_{min} to T_{max} and V_{DD1} = 3.0 V to 3.6 V unless otherwise stated						
Parameter	**Symbol**	**Min.**	**Typ.**	**Max.**	**Units**	**Test Conditions**
Output voltage	V_{DD2A}	3	3.3	3.45	V	T_{min} to T_{max}; full V_{DD1} and I_{DD2} operating range
Output current	I_{DD2}	80			mA	Total available to internal coupler and external load
Overcurrent threshold	I_{DD2}		150		mA	Disable
			145			Re-enable
Short-circuit protection limited current		115	125	135	mA	
Controller-side quiescent supply current	I_{DD1AQ}		200	240	mA	No external load on V_{DD2}
Controller-side supply current	I_{DD1A}		380	440	mA	Maximum DC-DC convertor load
Line regulation	$\Delta V_{DD2}/\Delta V_{DD1A}$		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	$V_{DD2-RIPPLE}$			5	mV_{P-P}	20 MHz bandwidth; I_{DD2} = max.
			1			1 kHz bandwidth; I_{DD2} = 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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Isolation Specifications

Parameter	Symbol	Min.	Typ.	Max.	Units	Test Conditions
Creepage distance (external)		8.03	8.3		mm	Per IEC 60601
Total barrier thickness (internal)		0.013	0.016		mm	
Barrier resistance	R_{IO}		$>10^{14}$		Ω	500 V_{RMS}
Barrier capacitance	C_{IO}		7		pF	f = 1 MHz
Leakage current			0.2		μA_{RMS}	240 V_{RMS}, 60 Hz
Comparative tracking index	CTI	≥600			V_{RMS}	Per IEC 60112
Barrier life			44000		Years	100°C, 1000 V_{RMS}, 60% CL activation energy

Thermal Characteristics

Parameter	Symbol	Min.	Typ.	Max.	Units	Test Conditions
Junction–ambient thermal resistance	θ_{JA}		67		°C/W	Double-sided PCB with thermal vias in free air
Junction–case (top) thermal resistance	θ_{JC}		12		°C/W	Double-sided PCB with thermal vias in free air
Junction–ambient thermal resistance	θ_{JA}		46		°C/W	2s2p PCB with thermal vias per JESD51 with thermal vias in free air
Junction–case (top) thermal resistance	θ_{JC}		9		°C/W	2s2p PCB with thermal vias per JESD51 with thermal vias in free air
Power dissipation	P_D			1.6	W	

Notes:

1. Absolute Maximum specifications mean the device will not be damaged if operated under these conditions. It does not guarantee performance.
2. PWD is defined as $|t_{PHL} - t_{PLH}|$. %PWD is equal to PWD divided by pulse width.
3. t_{PSK} is the magnitude of the worst-case difference in t_{PHL} and/or t_{PLH} between devices at 25°C.
4. CM_H is the maximum common mode voltage slew rate that can be sustained while maintaining $V_O > 0.8\ V_{DD2}$. CM_L is the maximum common mode input voltage that can be sustained while maintaining $V_O < 0.8$ V. The common mode voltage slew rates apply to both rising and falling common mode voltage edges.
5. Device is considered a two terminal device: pins 1–8 shorted and pins 9–16 shorted.
6. Minimum pulse width is the minimum value at which specified PWD is guaranteed.
7. The relevant test and measurement methods are given in the Electromagnetic Compatibility section.
8. External magnetic field immunity is improved by this factor if the field direction is “end-to-end” rather than to “pin-to-pin” (see diagram in the Electromagnetic Compatibility section).

Device Operation

DC-DC Convertor Operation

The DC-DC convertor block diagram is shown in Figure 1:

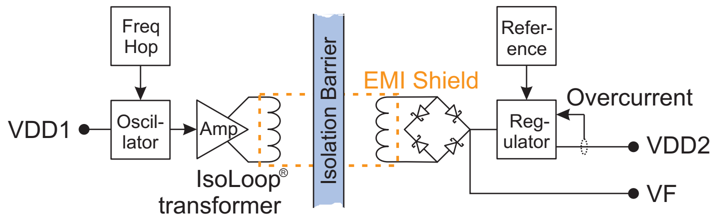


Figure 1. DC-DC convertor block diagram.

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.

A unique ceramic/polymer composite barrier provides best-in-class 6 kV isolation with virtually unlimited barrier life.

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.

Simple Capacitive Decoupling

The only external parts required are a 0.1 µF capacitor placed as close as possible to the V_{DD1B} supply pin, a 10 µF ceramic capacitor for the V_{DD2} pin, and a 0.1 µF/16 V filter capacitor near the V_F pin. This low external parts count reduces board area and cost.

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.

GMR Isolator Operation

An equivalent circuit for each of the Giant Magnetoresistor (GMR) isolator channels is shown in Figure 2:

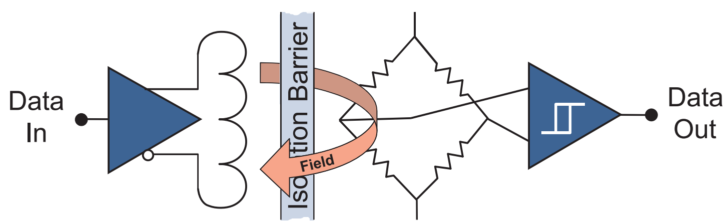


Figure 2. Isolator model signal path.

The GMR isolator signal path starts with a buffered input signal that is driven through an ultraminiature coil. This generates a small magnetic field that changes the electron spin polarization of GMR resistors, which are configured as a Wheatstone bridge. The change in spin polarization of the resistors creates a bridge voltage which drives an output comparator to construct an isolated version of the input signal. GMR is inherently high speed and low distortion.

Dynamic Power Consumption

IsoLoop Isolators achieve their low power consumption from the way they transmit data across the isolation barrier. By detecting the edge transitions of the input logic signal and converting these to narrow current pulses, a magnetic field is created around the GMR Wheatstone bridge. Depending on the direction of the magnetic field, the bridge causes the output comparator to switch following the input logic signal. Since the current pulses are narrow, about 2.5 ns, the power consumption is independent of mark-to-space ratio and solely dependent on frequency. This has obvious advantages over optocouplers, which have power consumption heavily dependent on mark-to-space ratio.

Power consumption increases with frequency for the input side of each channel, but output-side power consumption is constant for a particular isolator channel. For channels with inputs on the V_{DD2} side, the dynamic power consumption must be provided by the DC-DC convertor, so V_{DD1B} supply current increases with the frequency of that channel.

Current Drawn From the Output of the DC-DC Convertor by the Coupler Section
The current drawn from the output of the DC-DC convertor by the coupler section consists of the coupler's isolated-side quiescent current, plus, in the case of the IL7614V, isolated-side dynamic current. So, for example, for an IL7614V, the isolated-side quiescent current is 3.5 mA, the dynamic current is 0.24 mA/Mbps, so if the coupler is running at 100 Mbps, the dynamic current is 24 mA and the total current is 27.5 mA. Since the DC-DC convertor can supply up to 80 mA, the IL7614 can therefore supply up to 52.5 mA to external loads. Of course it can supply more if the coupler channels are running below full speed.

Maintaining Creepage
Creepage distances are often critical in isolated circuits. In addition to meeting JEDEC standards, NVE isolator packages have unique creepage specifications. Standard pad libraries often extend under the package, compromising creepage and clearance. Similarly, ground planes, if used, should be spaced to avoid compromising clearance. Package drawings and recommended pad layouts are included in this datasheet.

Coupler Status on Start-up and Shut Down
To minimize power dissipation, coupler input signals are differentiated and then latched on the output side of the isolation barrier to reconstruct the signal. This could result in an ambiguous output state depending on power up, shutdown and power loss sequencing. Therefore, the designer should consider including an initialization signal in the start-up circuit. Initialization consists of toggling the input either high then low, or low then high.

Power and Thermal Management
Under most circumstances, the IL76xx operates well within its power and thermal limits.

Power dissipated by the device consists of the DC-DC convertor plus the coupler, which is:

$$P_{DEVICE} = (V_{DD1A} \times I_{DD1A}) + (V_{DD1B} \times I_{DD1B}) - P_{EXT}$$

where P_{EXT} is the power dissipated by external loads, if any, on the DC-DC convertor output.

Power and Thermal Management may be an issue, however, if the coupler is operating at high speed and there are external loads on the DC-DC convertor. For example, if all four channels of an IL7615V runs at 100 Mbps and the DC-DC convertor runs at its maximum load, the coupler section will draw 102 mA maximum from V_{DD1B} (1.75 mA quiescent + 1 mA/Mbps dynamic worst case), and the DC-DC convertor will draw 440 mA maximum. If the V_{DD1} supply voltage is 3.3 volts, the total input power is 1.79 watts. The coupler section of the IL7615V draws a maximum of 7 mA from the isolated side of the DC-DC convertor, so the remaining 73 mA of DC-DC convertor capacity, or 0.24 watts, is assumed to be dissipated by an external load, leaving 1.55 watts of power dissipation in the IL7615V.

Junction-to-ambient thermal resistance is 46 °C/W with a 2s2p circuit board, so the temperature rise is 71 °C, so the maximum ambient temperature is 79 °C to stay below the maximum recommended operating junction temperature is 150 °C in this worst-case scenario.

Board Thermal Optimization
Board layout can be optimized for thermal performance if necessary. A double sided, double buried power plane ("2s2p") board maximizes thermal performance. Thermal vias should be used between the power plane and the board surfaces. All of the IC ground pins should be connected, with wide traces to help cool the leadframe.

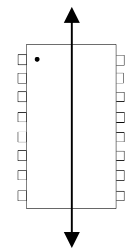
Maintaining Creepage
Creepage distances are often critical in isolated circuits. In addition to meeting JEDEC standards, NVE isolator packages have unique creepage specifications. Standard pad libraries often extend under the package, compromising creepage and clearance. Similarly, ground planes, if used, should be spaced to avoid compromising clearance. Package drawings and recommended pad layouts are included in this datasheet.

Inherently Low EMI
IL76xx-Series parts designed for compliance with IEC 61000-6-3, IEC 61000-6-4, CISPR, and FCC Class A standards for emissions.

The DC-DC convertor oscillator operates above 88 MHz, where emission limits are higher since there is less risk of interference with 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 generally not required for EMI mitigation.

High Magnetic Immunity
These parts are fully compliant with IEC 61000-6-1 and IEC 61000-6-2 magnetic immunity standards.



The coupler's Wheatstone bridge configuration and differential magnetic field signaling ensure excellent EM immunity. Immunity to external magnetic fields is even higher if the field direction is "end-to-end" (rather than to "pin-to-pin") as shown at right.

Typical Performance Graphs

The following graphs show typical performance:

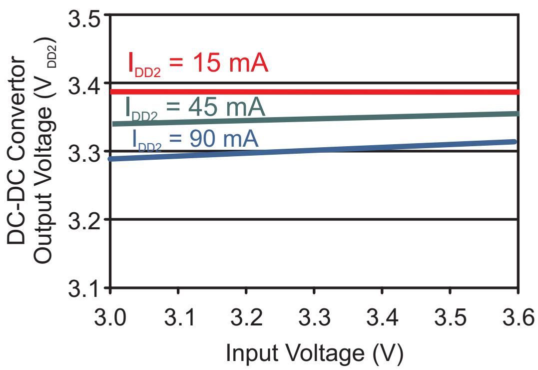


Figure 3. Typical DC-DC convertor line regulation.

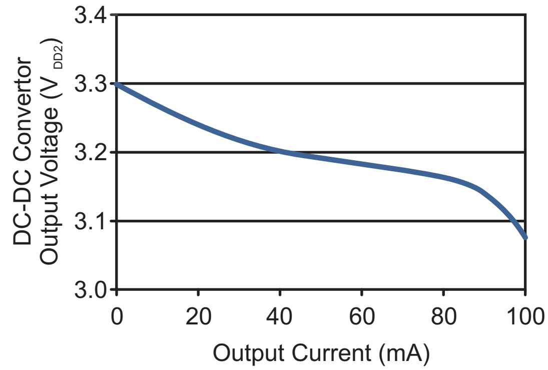


Figure 4. Typical DC-DC convertor load regulation (V_{DD1} = 3.3 V).

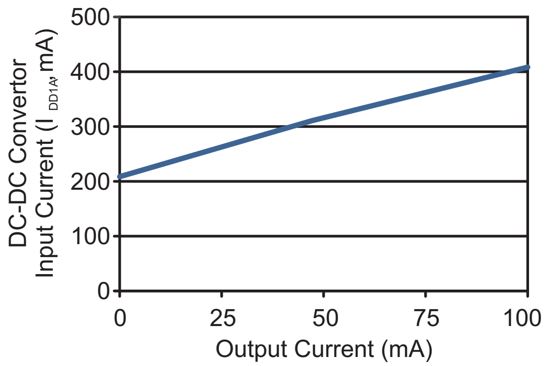


Figure 5. Typical DC-DC convertor supply current versus output current (V_{DD1} = 3.3 V).

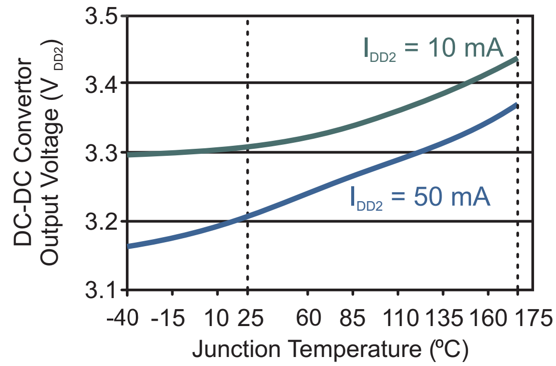


Figure 6. Typical DC-DC convertor output versus temperature (V_{DD1A} = 3.3 V).

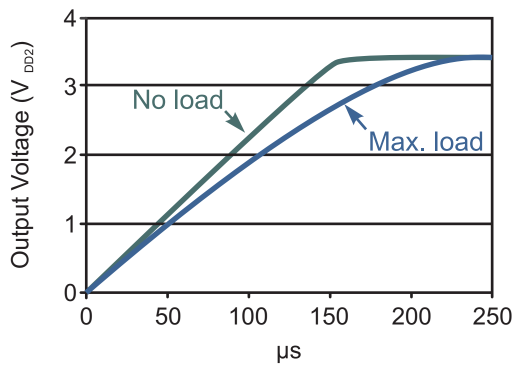


Figure 7. Typical DC-DC convertor startup.

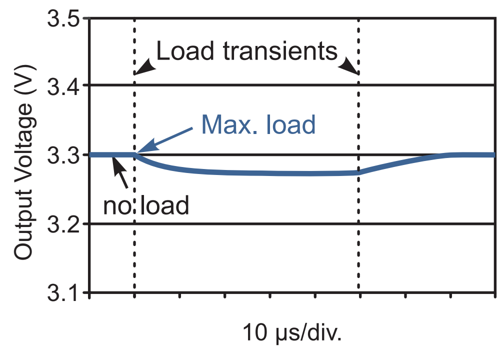


Figure 8. DC-DC convertor transient response.

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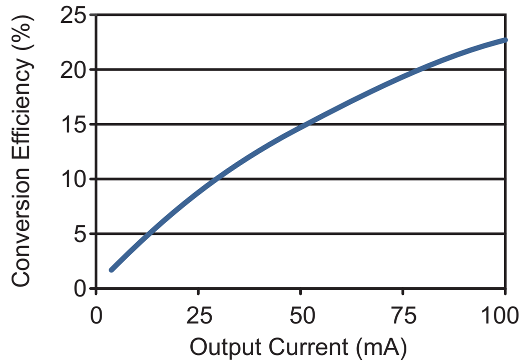


Figure 9. Typ. DC-DC convertor power efficiency (V_{DD1} = 3.3 V; 25 °C).

Typical Applications

Isolated SPI / MICROWIRE ADC interface:

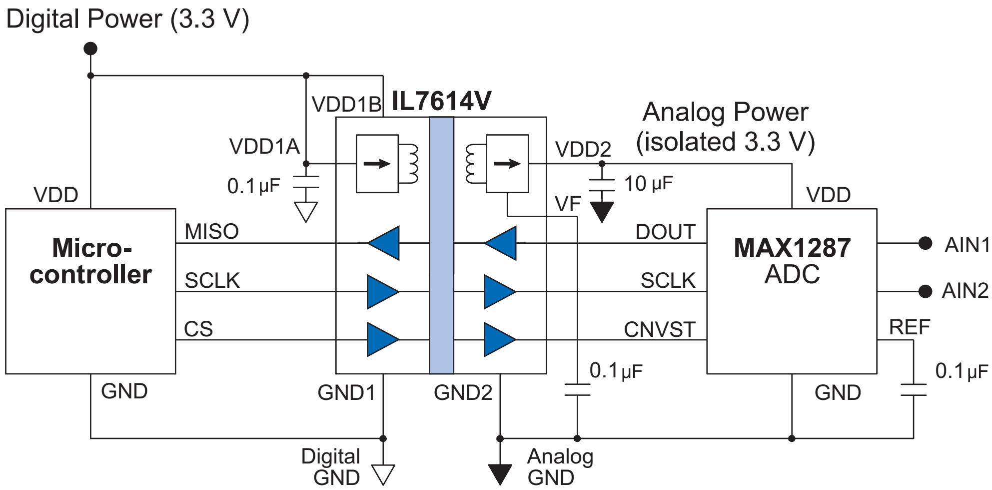


Figure 10. Isolated ADC serial interface.

The IL7614V provides an isolated analog power supply to significantly improve noise performance of a successive-approximation ADC, and also isolates the serial interface. This circuit can be used for other three-wire SPI or MICROWIRE peripherals such as DACs or sensors.

Double-isolated parallel DAC interface:

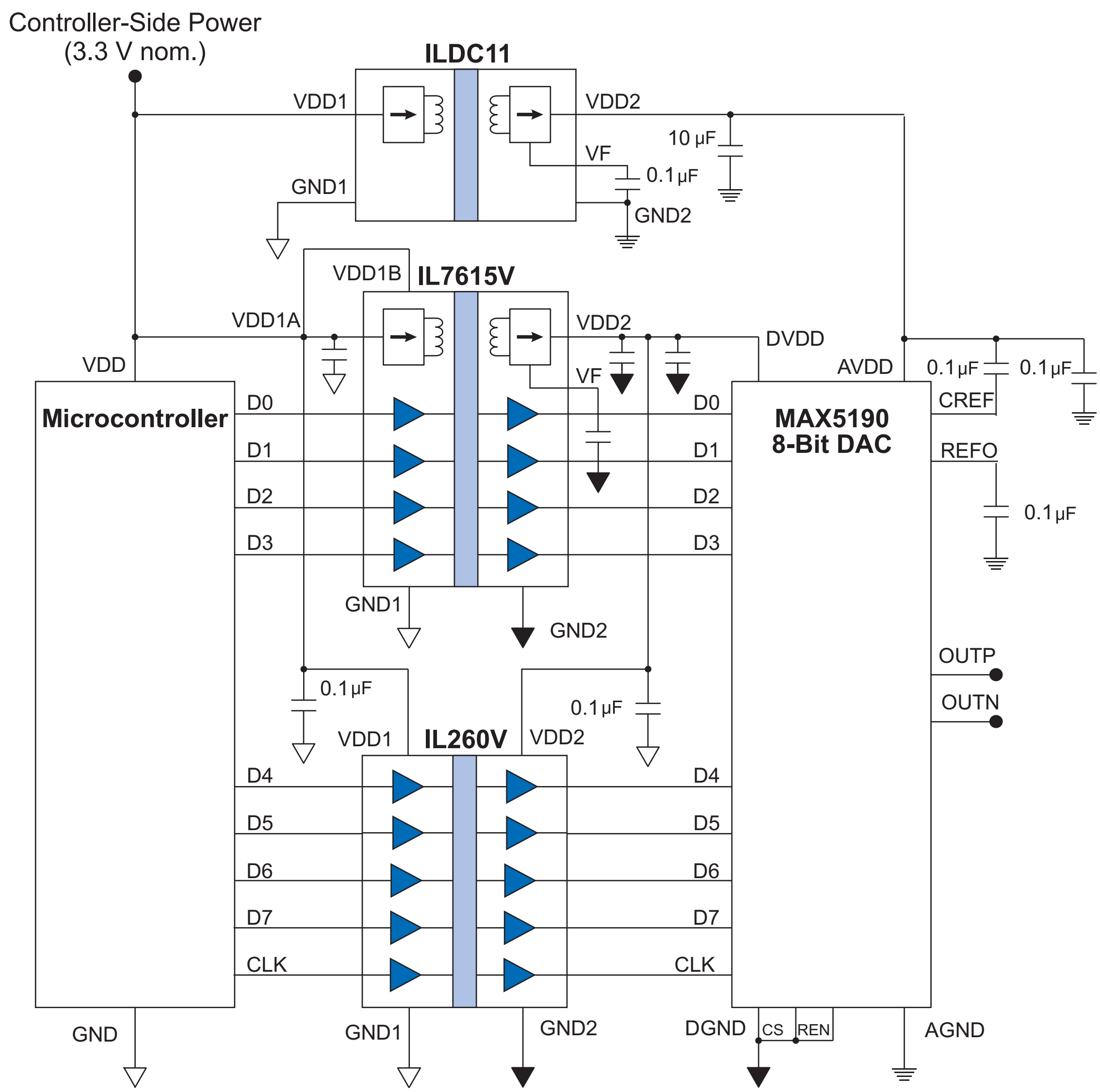


Figure 11. Double-isolated parallel DAC interface.

The IL7615V plus an IL2607V provide isolated digital power plus nine channels of isolation. This allows isolation of an eight-bit parallel peripheral such as a high-speed digital-to-analog convertor. The 110 Mbps speed of the IL7615V and IL717V couplers support the 40 MHz DAC used in this circuit. A separate ILDC11-15E DC-DC convertor provides an isolated analog power supply to improve noise performance by preventing digital noise from affecting the analog section of the DAC. The ILDC11-15E's extremely low ripple also enhances the DAC's noise performance.

Isolated interface to multiple SPI sensors:

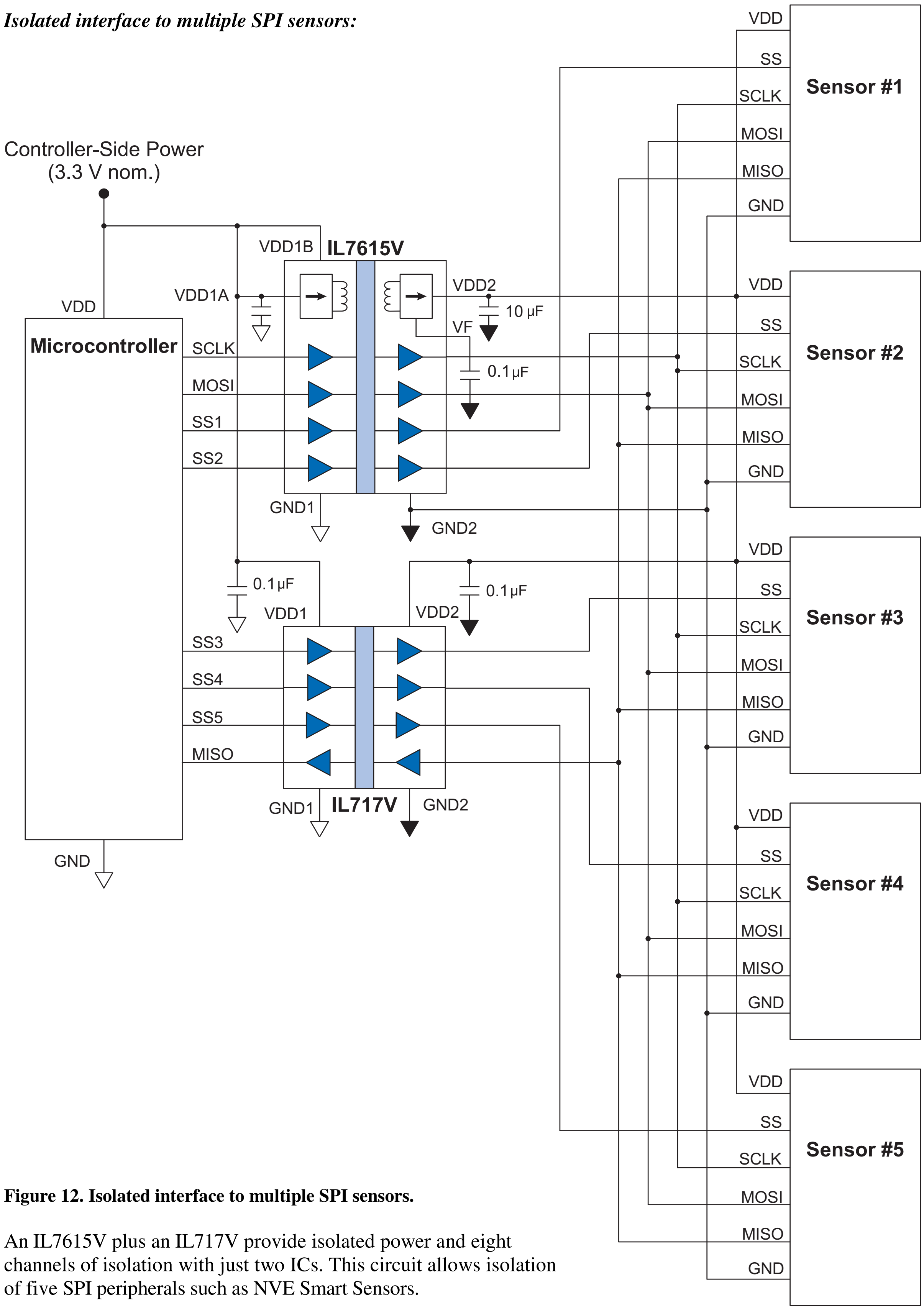
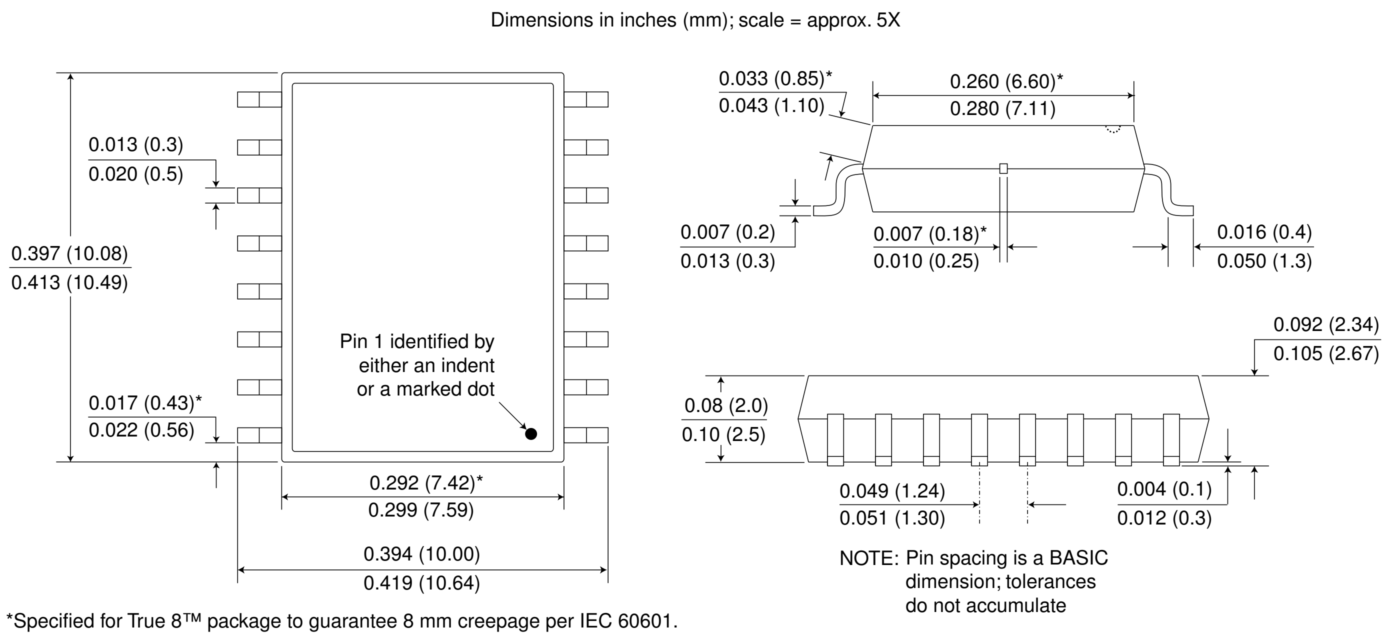


Figure 12. Isolated interface to multiple SPI sensors.

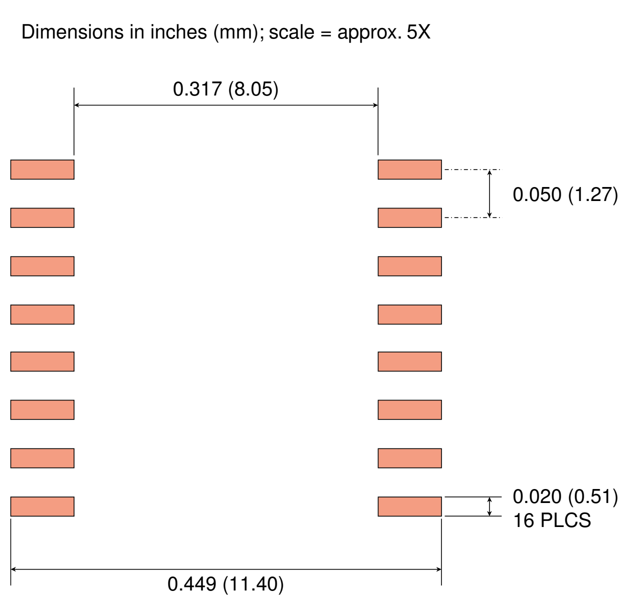
An IL7615V plus an IL717V provide isolated power and eight channels of isolation with just two ICs. This circuit allows isolation of five SPI peripherals such as NVE Smart Sensors.

Package Drawing



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

Recommended Pad Layout



Available Part Numbers

Part Number	Channels (transmit/receive)	Bulk Packaging	RoHS?
IL7621VE	1 / 1	Tubes (50 pcs.)	RoHS
IL7614VE	2 / 1		
IL7615VE	4 / 0		
IL7621VE-TR7	1 / 1	7-inch reels (up to 450 pcs.)	
IL7614VE-TR7	2 / 1		
IL7615VE-TR7	4 / 0		
IL7621VE-TR13	1 / 1	13-inch reels (up to 1500 pcs.)	
IL7614VE-TR13	2 / 1		
IL7615VE-TR13	4 / 0		
IL7621V	1 / 1	Tubes (50 pcs.)	SnPb finish (non-RoHS; Special Order)
IL7614V	2 / 1		
IL7615V	4 / 0		
IL7621V-TR7	1 / 1	7-inch reels (up to 450 pcs.)	
IL7614V-TR7	2 / 1		
IL7615V-TR7	4 / 0		
IL7621V-TR13	1 / 1	13-inch reels (up to 1500 pcs.)	
IL7614V-TR13	2 / 1		
IL7615V-TR13	4 / 0		

Revision History

ISB-DS-001-IL4685-PRELIM	**Change**
July 2020	• Preliminary release.

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