



16 Ω, Low Parasitic Capacitance and Leakage, +12 V / +5 V / +3 V / ± 5 V Quad SPST Switches

DESCRIPTION

The DG411LE, DG412LE, and DG413LE are monolithic quad single-pole-single-throw analog switches. The DG411LE and DG412LE differ only in that they respond to opposite logic levels. The DG413LE has two normally open and two normally closed switches. It can be given various configurations, including four SPST, two SPDT, and one DPDT.

The DG411LE, DG412LE, and DG413LE offer low on resistance of 16 Ω, low parasitic capacitance of 15 pF switch on capacitance, and low charge injection over the signal swing range.

The DG411LE, DG412LE, and DG413LE operate on single and dual supplies. Single supply voltage ranges from 3 V to 16 V while dual supply operation is recommended with ± 3 V to ± 8 V. Each switch conducts equally well in both direction when on, and blocks input voltages up to the supply levels when off.

The DG411LE, DG412LE, and DG413LE are available in 16 lead TSSOP, SOIC, and PDIP packages.

FEATURES

- 3 V to 16 V single supply or ± 3 V to ± 8 V dual supply
- On-resistance $R_{DS(on)}$: 16 Ω
- Low parasitic capacitance:
 - $C_{D(ON)}$: 15 pF
 - $C_{S(OFF)}$: 5 pF
- Less than 8 pC charge injection over the full signal swing range
- Fast switching t_{ON} : 16 ns
 t_{OFF} : 9 ns
- TTL, CMOS compatible
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912



Note

* This datasheet provides information about parts that are RoHS-compliant and / or parts that are non-RoHS-compliant. For example, parts with lead (Pb) terminations are not RoHS-compliant. Please see the information / tables in this datasheet for details.

BENEFITS

- Wide operation voltage range
- Low signal errors and distortion
- Fast switching time
- Minimized switching glitch

APPLICATIONS

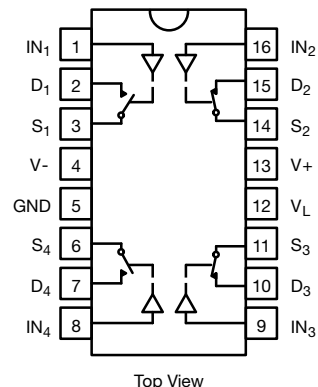
- Automatic test equipment
- Data acquisition systems
- Meters and instruments
- Medical and healthcare systems
- Communication systems
- Audio and video signal routing
- Relay replacement
- Battery powered systems
- Computer peripherals
- Audio and video signal routing

FUNCTIONAL BLOCK DIAGRAM AND PIN CONFIGURATION

DG411LE, DG412LE
Dual-In-Line, TSSOP and SOIC



DG413LE
Dual-In-Line, TSSOP and SOIC





TRUTH TABLE		
LOGIC	DG411LE	DG412LE
0	ON	OFF
1	OFF	ON

Logic "0" ≤ 0.8 VLogic "1" ≥ 2.4 V

TRUTH TABLE		
LOGIC	SW ₁ , SW ₄	SW ₂ , SW ₃
0	OFF	ON
1	ON	OFF

Logic "0" ≤ 0.8 VLogic "1" ≥ 2.4 V

ORDERING INFORMATION				
TEMP. RANGE	CONFIGURATION	PACKAGE	PART NUMBER	MIN. ORDER / PACK. QUANTITY
-40 °C to +85 °C Lead-free	DG411LE	16-pin TSSOP	DG411LEDQ-GE3	Tube 360 units
			DG411LEDQ-T1-GE3	Tape and reel, 3000 units
		16-pin SOIC	DG411LEDY-GE3	Tube 500 units
			DG411LEDY-T1-GE3	Tape and reel, 2500 units
		16-pin PDIP	DG411LEDJ-GE3	Tube 500 units
			DG412LE	16-pin TSSOP
	DG412LE	DG412LEDQ-T1-GE3	Tape and reel, 3000 units	
		16-pin SOIC	DG412LEDY-GE3	
	16-pin PDIP		DG412LEDY-T1-GE3	Tape and reel, 2500 units
		DG413LE	16-pin TSSOP	DG412LEDJ-GE3
	DG413LEDQ-GE3			Tube 360 units
	16-pin SOIC		DG413LEDQ-T1-GE3	Tape and reel, 3000 units
DG413LEDY-GE3			Tube 500 units	
16-pin PDIP	DG413LEDY-T1-GE3		Tape and reel, 2500 units	
	DG413LEDJ-GE3		Tube 500 units	

ABSOLUTE MAXIMUM RATINGS			
PARAMETER		LIMIT	UNIT
V ₊ to V ₋		-0.3 to +18	V
GND to V ₋		18	
V _L		(GND -0.3) to (V ₊) +0.3	
I _N ^a , V _S , V _D		-0.3 to (V ₊) +0.3 or 30 mA, whichever occurs first	
Continuous Current (Any terminal)		30	mA
Peak Current, S or D (Pulsed 1 ms, 10 % duty cycle)		100	
Storage Temperature	(DQ, DY suffix)	-65 to +125	°C
	(AK suffix)	-65 to +150	
Power Dissipation (Packages) ^b	16-pin TSSOP ^c	450	mW
	16-pin SOIC ^d	650	
	16-pin CerDIP ^e	900	
ESD Human Body Model (HBM); per ANSI / ESDA / JEDEC [®] JS-001		2500	V
Latch Up Current, per JESD78D		400	mA

Notes

- Signals on S_x, D_x, or I_{Nx} exceeding V₊ or V₋ will be clamped by internal diodes. Limit forward diode current to maximum current ratings.
- All leads welded or soldered to PC board.
- Derate 7 mW/°C above 75 °C.
- Derate 7.6 mW/°C above 75 °C
- Derate 12 mW/°C above 75 °C.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.



SPECIFICATIONS ^a (Single Supply 12 V)									
PARAMETER	SYMBOL	TEST CONDITIONS UNLESS OTHERWISE SPECIFIED V ₊ = 12 V, V ₋ = 0 V V _L = 5 V, V _{IN} = 2.4 V, 0.8 V ^f	TEMP. ^b	TYP. ^c	A SUFFIX LIMITS -55 °C to +125 °C		D SUFFIX LIMITS -40 °C to +85 °C		UNIT
					MIN. ^d	MAX. ^d	MIN. ^d	MAX. ^d	
					Analog Switch				
Analog Signal Range ^e	V _{ANALOG}		Full	-	0	12	0	12	V
Drain-Source On-Resistance	R _{DS(on)}	V ₊ = 10.8 V, V ₋ = 0 V I _S = 10 mA, V _D = 2/9 V	Room	16	-	26	-	26	Ω
			Full	-	-	40	-	35	
Switch Off Leakage Current	I _{S(off)}	V _D = 1/11 V, V _S = 11/1 V	Room	-	-1	1	-1	1	nA
			Full	-	-15	15	-10	10	
	I _{D(off)}		Room	-	-1	1	-1	1	
			Full	-	-15	15	-10	10	
Channel On Leakage Current	I _{D(on)}	V _S = V _D = 11/1 V	Room	-	-1	1	-1	1	
			Full	-	-15	15	-10	10	
Digital Control									
Input Current, VIN Low	I _{IL}	V _{IN} under test = 0.8 V	Full	0.01	-1.5	1.5	-1	1	μA
Input Current, VIN High	I _{IH}	V _{IN} under test = 2.4 V	Full		-1.5	1.5	-1	1	
Dynamic Characteristics									
Turn-On Time	t _{ON}	R _L = 300 Ω, C _L = 35 pF, V _S = 5 V, see figure 2	Room	16	-	50	-	50	ns
			Full	-	-	70	-	60	
Turn-Off Time	t _{OFF}		Room	9	-	30	-	30	
			Full	-	-	48	-	40	
Break-Before-Make Time Delay	t _D	DG413L only, V _S = 5 V, R _L = 300 Ω, C _L = 35 pF	Room	5	-	-	-	-	
Charge Injection ^e	Q	V _g = 0 V, R _g = 0 Ω, C _L = 10 nF	Room	6.6	-	-	-	-	pC
Off-Isolation ^e	OIRR	R _L = 50 Ω, C _L = 5 pF, f = 1 MHz	Room	68.4	-	-	-	-	dB
Channel-to-Channel Crosstalk ^e	X _{TALK}		Room	114	-	-	-	-	
Source Off Capacitance ^e	C _{S(off)}		f = 1 MHz	Room	5	-	-	-	-
Drain Off Capacitance ^e	C _{D(off)}	Room		6	-	-	-	-	
Channel-On Capacitance ^e	C _{D(on)}	Room		15	-	-	-	-	
Power Supplies									
Positive Supply Current	I ₊	V _{IN} = 0 V or 5 V	Room	0.02	-	1	-	1	μA
			Full	-	-	7.5	-	5	
Negative Supply Current	I ₋		Room	-0.002	-1	-	-1	-	
			Full	-	-7.5	-	-5	-	
Logic Supply Current	I _L		Room	0.002	-	1	-	1	
			Full	-	-	7.5	-	5	
Ground Current	I _{GND}		Room	-0.002	-1	-	-1	-	
			Full	-	-7.5	-	-5	-	

Notes

- a. Refer to PROCESS OPTION FLOWCHART.
- b. Room = 25 °C, full = as determined by the operating temperature suffix.
- c. Typical values are for DESIGN AID ONLY, not guaranteed nor subject to production testing.
- d. The algebraic convention whereby the most negative value is a minimum and the most positive a maximum, is used in this datasheet.
- e. Guaranteed by design, not subject to production test.
- f. V_{IN} = input voltage to perform proper function.
- g. Leakage parameters are guaranteed by worst case test conditions and not subject to test.



SPECIFICATIONS ^a (Dual Supply ± 5 V)										
PARAMETER	SYMBOL	TEST CONDITIONS UNLESS OTHERWISE SPECIFIED $V_+ = 5$ V, $V_- = -5$ V $V_L = 5$ V, $V_{IN} = 2.4$ V, 0.8 V ^f	TEMP. ^b	TYP. ^c	A SUFFIX LIMITS -55 °C to +125 °C		D SUFFIX LIMITS -40 °C to +85 °C		UNIT	
					MIN. ^d	MAX. ^d	MIN. ^d	MAX. ^d		
Analog Switch										
Analog Signal Range ^e	V_{ANALOG}		Full	-	-5	5	-5	5	V	
Drain-Source On-Resistance	$R_{DS(on)}$	$V_+ = 5$ V, $V_- = -5$ V, $I_S = 10$ mA, $V_D = \pm 3.5$ V	Room	18	-	30	-	30	Ω	
			Full	-	-	42	-	37		
Switch Off Leakage Current ^g	$I_{S(off)}$	$V_+ = 5.5$, $V_- = -5.5$ V, $V_D = \pm 4.5$ V, $V_S = \pm 4.5$ V	Room	-	-1	1	-1	1	nA	
			Full	-	-15	15	-10	10		
	Room		-	-1	1	-1	1			
	Full		-	-15	15	-10	10			
Channel On Leakage Current ^g	$I_{D(on)}$	$V_+ = 5.5$ V, $V_- = -5.5$ V, $V_S = V_D = \pm 4.5$ V	Room	-	-1	1	-1	1		
			Full	-	-15	15	-10	10		
Digital Control										
Input Current, V_{IN} Low ^e	I_{IL}	V_{IN} under test = 0.8 V	Full	0.05	-1.5	1.5	-1	1	μ A	
Input Current, V_{IN} High ^e	I_{IH}	V_{IN} under test = 2.4 V	Full	0.05	-1.5	1.5	-1	1		
Dynamic Characteristics										
Turn-On Time ^e	t_{ON}	$R_L = 300 \Omega$, $C_L = 35$ pF, $V_S = \pm 3.5$ V, see figure 2	Room	17	-	50	-	50	ns	
			Full	-	-	70	-	60		
Turn-Off Time ^e	t_{OFF}		Room	12	-	35	-	35		
			Full	-	-	50	-	40		
Break-Before-Make Time Delay ^e	t_D		DG413L only, $V_S = 3.5$ V, $R_L = 300 \Omega$, $C_L = 35$ pF	Room	5	-	-	-		-
Charge Injection ^e	Q		$V_g = 0$ V, $R_g = 0 \Omega$, $C_L = 10$ nF	Room	5.8	-	-	-		-
Off Isolation ^e	OIRR	$R_L = 50 \Omega$, $C_L = 5$ pF, $f = 1$ MHz	Room	68	-	-	-	-	dB	
Channel-to-Channel Crosstalk ^e	X_{TALK}		Room	113	-	-	-	-		
Source Off Capacitance ^e	$C_{S(off)}$		$f = 1$ MHz	Room	5	-	-	-	-	pF
Drain Off Capacitance ^e	$C_{D(off)}$	Room		6	-	-	-	-		
Channel On Capacitance ^e	$C_{D(on)}$	Room		14	-	-	-	-		
Power Supplies										
Positive Supply Current ^e	I_+	$V_{IN} = 0$ V or 5 V	Room	0.03	-	1	-	1	μ A	
			Full	-	-	7.5	-	5		
Negative Supply Current ^e	I_-		Room	-0.002	-1	-	-1	-		
			Full	-	-7.5	-	-5	-		
Logic Supply Current ^e	I_L		Room	0.002	-	1	-	1		
			Full	-	-	7.5	-	5		
Ground Current ^e	I_{GND}		Room	-0.002	-1	-	-1	-		
			Full	-	-7.5	-	-5	-		

Notes

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- g. Leakage parameters are guaranteed by worst case test conditions and not subject to test.



SPECIFICATIONS ^a (Single Supply 5 V)									
PARAMETER	SYMBOL	TEST CONDITIONS UNLESS OTHERWISE SPECIFIED $V_+ = 5\text{ V}$, $V_- = 0\text{ V}$ $V_L = 5\text{ V}$, $V_{IN} = 2.4\text{ V}$, 0.8 V^f	TEMP. ^b	TYP. ^c	A SUFFIX LIMITS -55 °C to +125 °C		D SUFFIX LIMITS -40 °C to +85 °C		UNIT
					MIN. ^d	MAX. ^d	MIN. ^d	MAX. ^d	
Analog Switch									
Analog Signal Range ^e	V_{ANALOG}		Full	-	-	5	-	5	V
Drain-Source On-Resistance ^e	$R_{DS(on)}$	$V_+ = 4.5\text{ V}$, $I_S = 5\text{ mA}$, $V_D = 1\text{ V}$, 3.5 V	Room	36	-	50	-	50	Ω
			Full	-	-	88	-	75	
Dynamic Characteristics									
Turn-On Time ^e	t_{ON}	$R_L = 300\ \Omega$, $C_L = 35\text{ pF}$, $V_S = 3.5\text{ V}$, see figure 2	Room	27	-	50	-	50	ns
			Hot	-	-	90	-	60	
Turn-Off Time ^e	t_{OFF}		Room	15	-	30	-	30	
			Hot	-	-	55	-	40	
Break-Before-Make Time Delay ^e	t_D	DG413L only, $V_S = 3.5\text{ V}$, $R_L = 300\ \Omega$, $C_L = 35\text{ pF}$	Room	11	-	-	-	-	
Charge Injection ^e	Q	$V_g = 0\text{ V}$, $R_g = 0\ \Omega$, $C_L = 10\text{ nF}$	Room	3.3	-	-	-	-	pC
Power Supplies									
Positive Supply Current ^e	I+	$V_{IN} = 0\text{ V or }5\text{ V}$	Room	0.02	-	1	-	1	μA
			Hot	-	-	7.5	-	5	
Negative Supply Current ^e	I-		Room	-0.002	-1	-	-1	-	
			Hot	-	-7.5	-	-5	-	
Logic Supply Current ^e	I_L		Room	0.002	-	1	-	1	
			Hot	-	-	7.5	-	5	
Ground Current ^e	I_{GND}		Room	-0.002	-1	-	-1	-	
			Hot	-	-7.5	-	-5	-	

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- e. Guaranteed by design, not subject to production test.
- f. V_{IN} = input voltage to perform proper function.
- g. Leakage parameters are guaranteed by worst case test conditions and not subject to test.



SPECIFICATIONS ^a (Single Supply 3 V)										
PARAMETER	SYMBOL	TEST CONDITIONS UNLESS OTHERWISE SPECIFIED $V_+ = 3\text{ V}, V_- = 0\text{ V}$ $V_L = 3\text{ V}, V_{IN} = 0.4\text{ V}, 2.0\text{ V}$ ^f	TEMP. ^b	TYP. ^c	ASUFFIX LIMITS -55 °C to +125 °C		D SUFFIX LIMITS -40 °C to +85 °C		UNIT	
					MIN. ^d	MAX. ^d	MIN. ^d	MAX. ^d		
Analog Switch										
Analog Signal Range ^e	V_{ANALOG}		Full	-	0	3	0	3	V	
Drain-Source On-Resistance	$R_{DS(on)}$	$V_+ = 2.7\text{ V}, V_- = 0\text{ V},$ $I_S = 5\text{ mA}, V_D = 0.5, 2.2\text{ V}$	Room	106	-	130	-	130	Ω	
			Full	-	-	150	-	140		
Switch Off Leakage Current ^g	$I_{S(off)}$	$V_+ = 3.3, V_- = 0\text{ V},$ $V_D = 1, 2\text{ V}, V_S = 2, 1\text{ V}$	Room	-	-1	1	-1	1	nA	
			Full	-	-15	15	-10	10		
	$I_{D(off)}$		Room	-	-1	1	-1	1		
			Full	-	-15	15	-10	10		
Channel On Leakage Current ^g	$I_{D(on)}$	$V_+ = 3.3\text{ V}, V_- = 0\text{ V},$ $V_S = V_D = 1, 2\text{ V}$	Room	-	-1	1	-1	1		
			Full	-	-15	15	-10	10		
Digital Control										
Input Current, V_{IN} Low	I_{IL}	V_{IN} under test = 0.4 V	Full	0.005	-1.5	1.5	-1	1	μA	
Input Current, V_{IN} High	I_{IH}	V_{IN} under test = 2.4 V	Full	0.005	-1.5	1.5	-1	1		
Dynamic Characteristics										
Turn-On Time	t_{ON}	$R_L = 300\ \Omega, C_L = 35\text{ pF},$ $V_S = 1.5\text{ V},$ see figure 2	Room	57	-	85	-	85	ns	
			Full	-	-	150	-	110		
Turn-Off Time	t_{OFF}		Room	25	-	60	-	60		
			Full	-	-	100	-	85		
Break-Before-Make Time Delay	t_D		DG413L only, $V_S = 1.5\text{ V},$ $R_L = 300\ \Omega, C_L = 35\text{ pF}$	Room	24	-	-	-		-
Charge Injection ^e	Q		$V_g = 0\text{ V}, R_g = 0\ \Omega, C_L = 10\text{ nF}$	Room	2	-	-	-		-
Off Isolation ^e	OIRR	$R_L = 50\ \Omega, C_L = 5\text{ pF}, f = 1\text{ MHz}$	Room	68	-	-	-	-	dB	
Channel-to-Channel Crosstalk ^e	X_{TALK}		Room	107	-	-	-	-		
Source Off Capacitance ^e	$C_{S(off)}$		f = 1 MHz	Room	6	-	-	-	-	pF
Drain Off Capacitance ^e	$C_{D(off)}$	Room		7	-	-	-	-		
Channel On Capacitance ^e	$C_{D(on)}$	Room		15	-	-	-	-		

Notes

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TYPICAL CHARACTERISTICS (25 °C, unless otherwise noted)



$R_{DS(on)}$ vs. Drain Voltage (Single Supply)



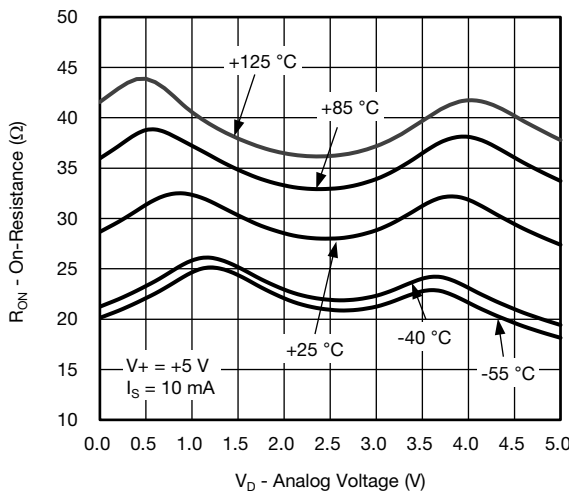
$R_{DS(on)}$ vs. Drain Voltage and Temperature (Single Supply)



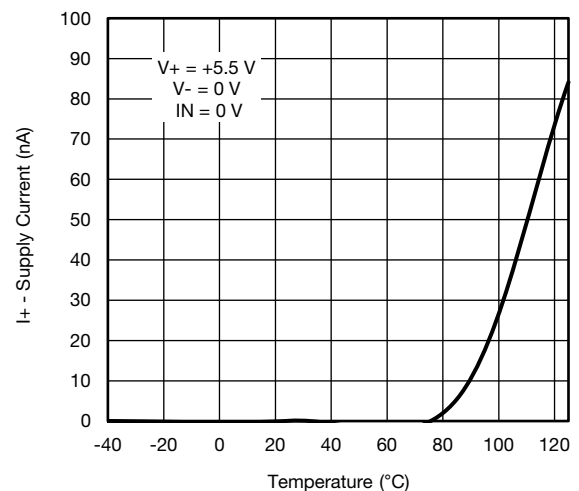
$R_{DS(on)}$ vs. Drain Voltage and Temperature



Supply Current vs. Temperature



$R_{DS(on)}$ vs. Drain Voltage and Temperature



Switching Time vs. Single Supply



TYPICAL CHARACTERISTICS (25 °C, unless otherwise noted)



Leakage Current vs. Drain Voltage



Charge Injection vs. Drain Voltage



Switching Time vs. Single Supply Voltage



Threshold vs. Single Supply Current



Switching Time vs. Dual Supply Voltage

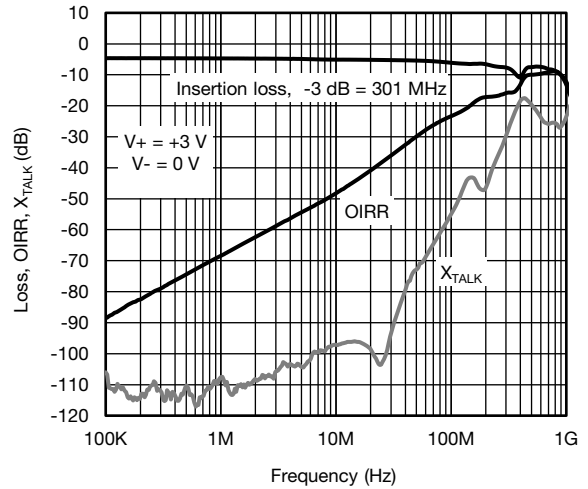


Drain Capacitance vs. Drain Voltage (Single Supply)

TYPICAL CHARACTERISTICS (25 °C, unless otherwise noted)



Drain Capacitance vs. Drain Voltage (Dual Supply)



Insertion Loss, Off Isolation and Crosstalk vs. Frequency

SCHEMATIC DIAGRAM (Typical Channel)

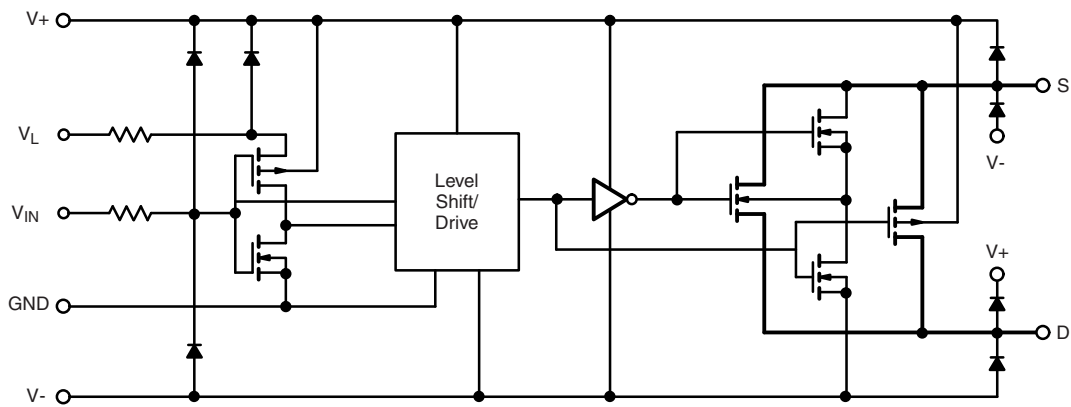


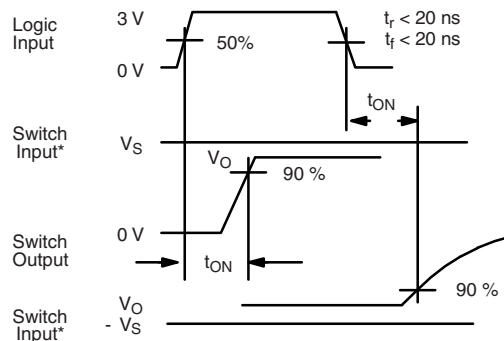
Fig. 1

TEST CIRCUITS



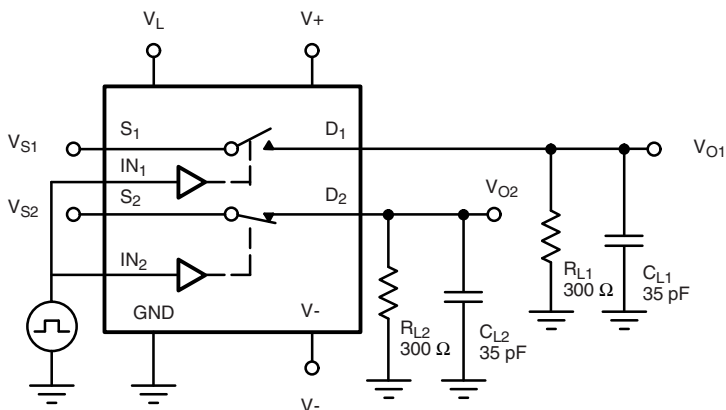
C_L (includes fixture and stray capacitance)

$$V_O = V_S \frac{R_L}{R_L + r_{DS(on)}}$$



Note: Logic input waveform is inverted for switches that have the opposite logic sense control

Fig. 2 - Switching Time



C_L (includes fixture and stray capacitance)

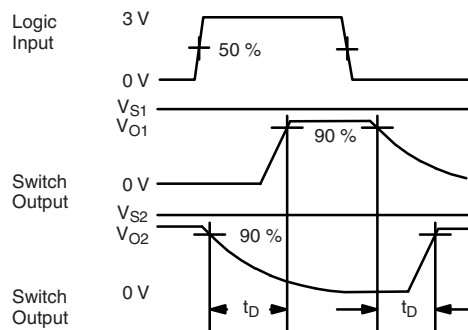
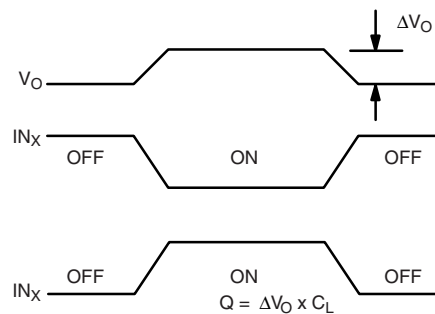
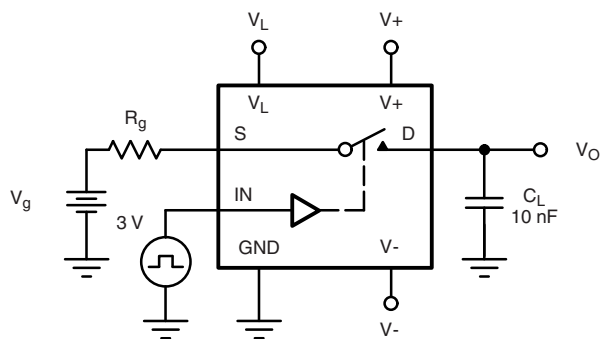
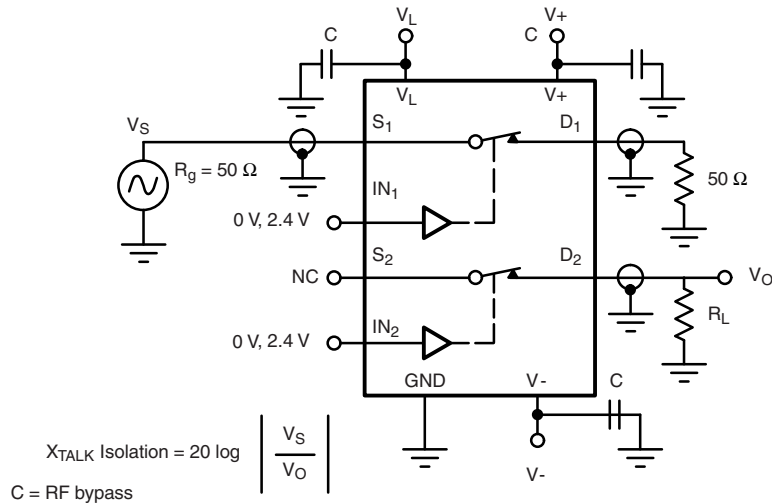
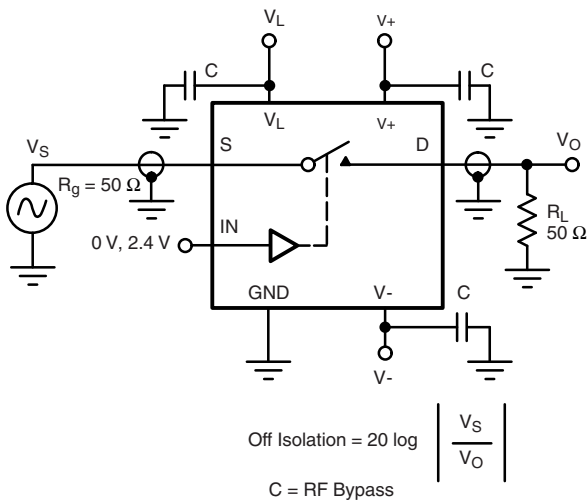
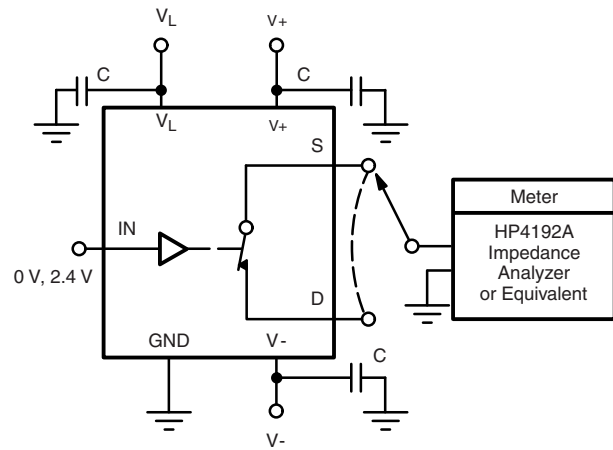


Fig. 3 - Break-Before-Make (DG413LE)



IN_x dependent on switch configuration Input polarity determined by sense of switch.

Fig. 4 - Charge Injection

TEST CIRCUITS

Fig. 5 - Crosstalk

Fig. 6 - Off-Isolation

Fig. 7 - Source / Drain Capacitances

Vishay Siliconix maintains worldwide manufacturing capability. Products may be manufactured at one of several qualified locations. Reliability data for Silicon Technology and Package Reliability represent a composite of all qualified locations. For related documents such as package/tape drawings, part marking, and reliability data, see www.vishay.com/ppg?78091.



SOIC (NARROW): 16-LEAD
JEDEC Part Number: MS-012

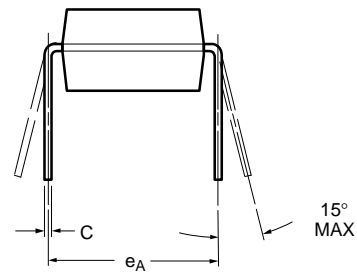


Dim	MILLIMETERS		INCHES	
	Min	Max	Min	Max
A	1.35	1.75	0.053	0.069
A ₁	0.10	0.20	0.004	0.008
B	0.38	0.51	0.015	0.020
C	0.18	0.23	0.007	0.009
D	9.80	10.00	0.385	0.393
E	3.80	4.00	0.149	0.157
e	1.27 BSC		0.050 BSC	
H	5.80	6.20	0.228	0.244
L	0.50	0.93	0.020	0.037
∅	0°	8°	0°	8°

ECN: S-03946—Rev. F, 09-Jul-01
DWG: 5300



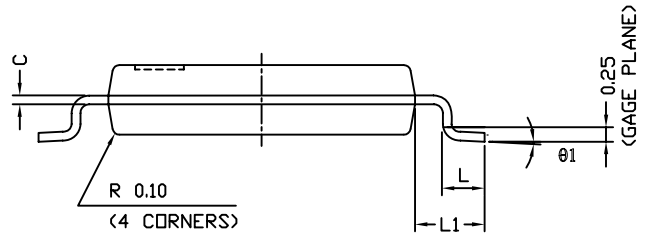
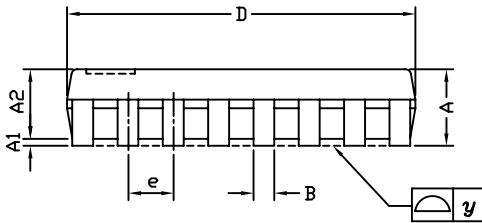
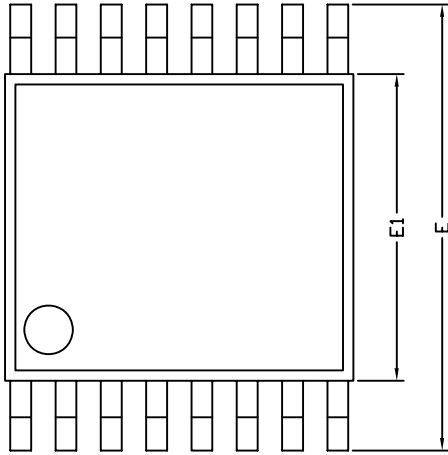
PDIP: 16-LEAD



Dim	MILLIMETERS		INCHES	
	Min	Max	Min	Max
A	3.81	5.08	0.150	0.200
A₁	0.38	1.27	0.015	0.050
B	0.38	0.51	0.015	0.020
B₁	0.89	1.65	0.035	0.065
C	0.20	0.30	0.008	0.012
D	18.93	21.33	0.745	0.840
E	7.62	8.26	0.300	0.325
E₁	5.59	7.11	0.220	0.280
e₁	2.29	2.79	0.090	0.110
e_A	7.37	7.87	0.290	0.310
L	2.79	3.81	0.110	0.150
Q₁	1.27	2.03	0.050	0.080
S	0.38	1.52	.015	0.060

ECN: S-03946—Rev. D, 09-Jul-01
DWG: 5482

TSSOP: 16-LEAD

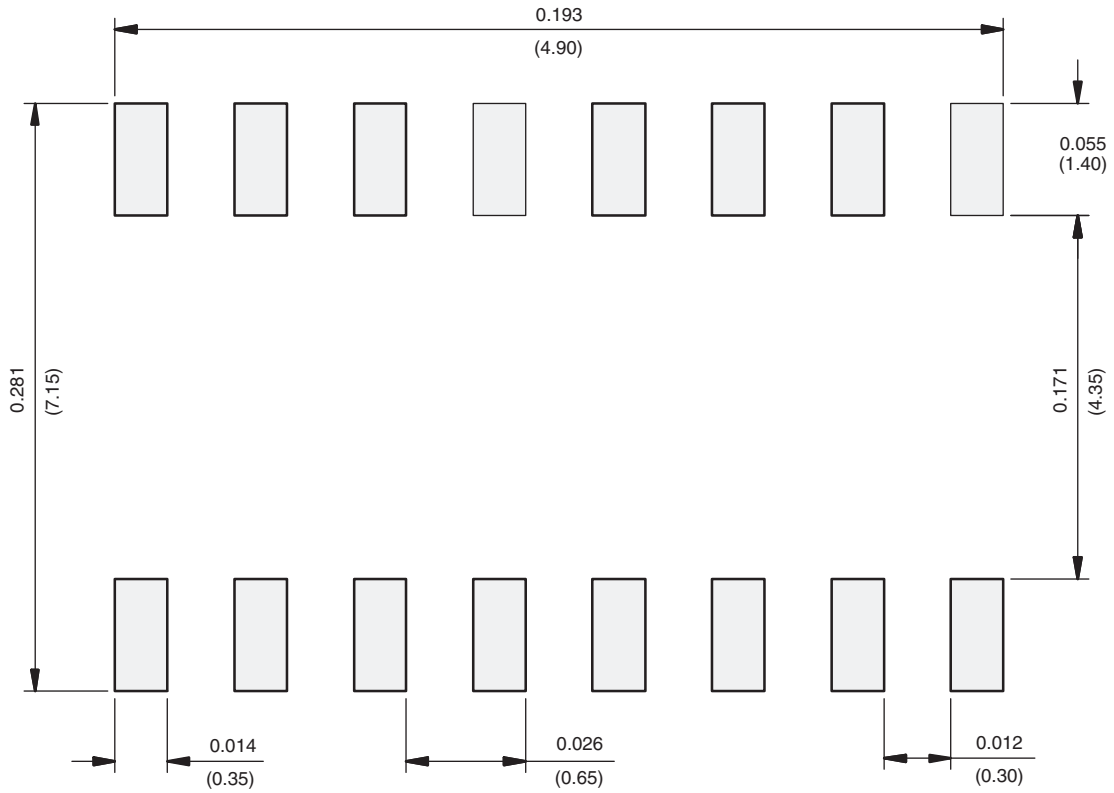


Symbols	DIMENSIONS IN MILLIMETERS		
	Min	Nom	Max
A	-	1.10	1.20
A1	0.05	0.10	0.15
A2	-	1.00	1.05
B	0.22	0.28	0.38
C	-	0.127	-
D	4.90	5.00	5.10
E	6.10	6.40	6.70
E1	4.30	4.40	4.50
e	-	0.65	-
L	0.50	0.60	0.70
L1	0.90	1.00	1.10
y	-	-	0.10
theta1	0°	3°	6°

ECN: S-61920-Rev. D, 23-Oct-06
DWG: 5624



RECOMMENDED MINIMUM PAD FOR TSSOP-16



Recommended Minimum Pads
Dimensions in inches (mm)

RECOMMENDED MINIMUM PADS FOR SO-16



Recommended Minimum Pads
Dimensions in Inches/(mm)

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- Помощь Конструкторского Отдела и консультации квалифицированных инженеров;
- Техническая поддержка проекта, помощь в подборе аналогов, поставка прототипов;
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- Система менеджмента качества сертифицирована по Международному стандарту ISO 9001;
- При необходимости вся продукция военного и аэрокосмического назначения проходит испытания и сертификацию в лаборатории (по согласованию с заказчиком);
- Поставка специализированных компонентов военного и аэрокосмического уровня качества (Xilinx, Altera, Analog Devices, Intersil, Interpoint, Microsemi, Actel, Aeroflex, Peregrine, VPT, Syfer, Eurofarad, Texas Instruments, MS Kennedy, Miteq, Cobham, E2V, MA-COM, Hittite, Mini-Circuits, General Dynamics и др.);

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JONHON

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