



# Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches

## General Description

The DG411F/DG412F/DG413F are quad, single-pole/single-throw (SPST), fault-protected analog switches. They are pin compatible with the industry-standard nonprotected DG411/DG412/DG413. These new switches feature fault-protected inputs and Rail-to-Rail® signal-handling capability. All terminals are protected from overvoltage faults up to  $\pm 36V$  with power on and up to  $\pm 40V$  with power off. During a fault condition, the COM, NO, or NC terminal becomes an open circuit and only microamperes of leakage current flow from the source. On-resistance is  $35\Omega$  (max) and is matched between switches to  $1.5\Omega$  (max) at  $+25^\circ C$ .

The DG411F has four normally closed (NC) switches. The DG412F has four normally open (NO) switches. The DG413F has two NC and two NO switches. These CMOS switches operate with dual power supplies ranging from  $\pm 4.5V$  to  $\pm 20V$  or a single supply between  $+9V$  and  $+36V$ . All digital inputs have  $+0.8V$  and  $+2.4V$  logic thresholds, ensuring both TTL and CMOS logic compatibility when using  $\pm 15V$  or a single  $+12V$  supply.

For supply voltages of  $\pm 5V$ ,  $+5V$ , and  $+3V$ , refer to the MAX4711/MAX4712/MAX4713 data sheet.

## Applications

Communication Systems  
Signal Routing  
Test Equipment  
Data Acquisition  
Industrial and Process Control Systems  
Avionics  
Redundant/Backup Systems

*Rail-to-Rail is a registered trademark of Nippon Motorola, Ltd.*

**Functional Diagram appears at end of data sheet.**

**Pin Configurations continued at end of data sheet.**

## Features

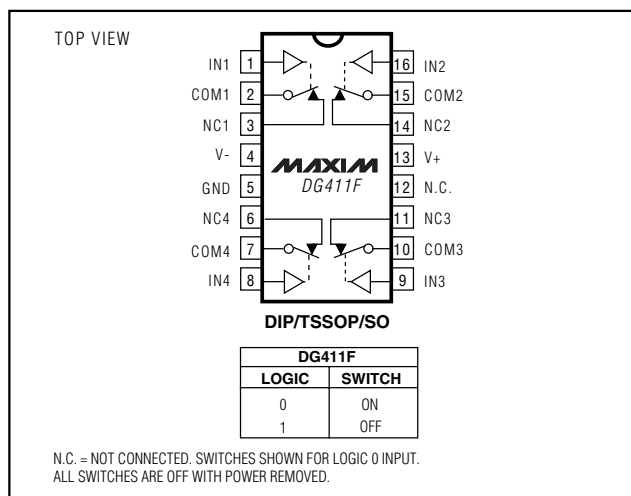
- ◆ No Power-Supply Sequencing Required
- ◆ Rail-to-Rail Signal Handling
- ◆ All Switches Off with Power Off
- ◆ All Switches Off when  $V_+$  is Off and  $V_-$  is On
- ◆  $\pm 40V$  Fault Protection with Power Off
- ◆  $\pm 36V$  Fault Protection with  $\pm 15V$  Supplies
- ◆ Control Line Fault Protection from  $V_- - 0.3V$  to  $V_- + 40V$
- ◆ Pin Compatible with Industry-Standard DG411/DG412/DG413
- ◆ 20ns (typ) Fault Response Time
- ◆  $35\Omega$  (max)  $R_{ON}$  with  $\pm 15V$  Supplies
- ◆  $\pm 4.5V$  to  $\pm 20V$  Dual Supplies
- ◆  $+9V$  to  $+36V$  Single Supply
- ◆ TTL- and CMOS-Compatible Logic Inputs with  $\pm 15V$  or Single  $+9V$  to  $+15V$  Supplies

## Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
DG411FEUE	$-40^\circ C$ to $+85^\circ C$	16 TSSOP
DG411FDY	$-40^\circ C$ to $+85^\circ C$	16 SO
DG411FDJ	$-40^\circ C$ to $+85^\circ C$	16 Plastic DIP

Ordering Information continued at end of data sheet.

## Pin Configurations



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## ABSOLUTE MAXIMUM RATINGS

(Voltages Referenced to GND)

V+	.....-0.3V to +44V
V-	.....-44V to +0.3V
V+ to V-	.....-0.3V to +44V
IN	..... (V- - 0.3V) to (V- + 40V)
NO <sub>-</sub> , NC <sub>-</sub> to COM <sub>-</sub> (Note 1)	..... -40V to +40V
COM <sub>-</sub> , NO <sub>-</sub> , NC <sub>-</sub> Voltage with Power On (Note 1)	..... -36V to +36V
COM <sub>-</sub> , NO <sub>-</sub> , NC <sub>-</sub> Voltage with Power Off (Note 1)	..... -40V to +40V
Continuous Current (any terminal)	..... ±30mA
Peak Current COM <sub>-</sub> , NO <sub>-</sub> , NC <sub>-</sub> (pulsed at 1ms, 10% duty cycle)	..... ±100mA

Continuous Power Dissipation (T<sub>A</sub> = +70°C)

16-Pin TSSOP (derate 9.4mW/°C above +70°C)	..... 755mW
16-Pin SO (derate 8.7mW/°C above +70°C)	..... 696mW
16-Pin Plastic DIP (derate 10.53mW/°C above +70°C)	..... 842mW
Operating Temperature Range	..... -40°C to +85°C
Junction Temperature	..... +150°C
Storage Temperature Range	..... -65°C to +160°C
Lead Temperature (soldering, 10s)	..... +300°C

**Note 1:** COM<sub>-</sub>, NO<sub>-</sub>, and NC<sub>-</sub> pins are fault protected. Signals on COM<sub>-</sub>, NO<sub>-</sub>, and NC<sub>-</sub> exceeding -36V to +36V may damage the device during power-on conditions. When the power is off, the maximum range is -40V to +40V.

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.

## ELECTRICAL CHARACTERISTICS—±15V Dual Supplies

(V<sub>+</sub> = +15V, V<sub>-</sub> = -15V, V<sub>IH</sub> = +2.4V, V<sub>IL</sub> = +0.8V, GND = 0, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Notes 2, 3)

PARAMETER	SYMBOL	CONDITIONS	T <sub>A</sub>	MIN	TYP	MAX	UNITS
ANALOG SWITCH							
Fault-Free Analog Signal Range	V <sub>COM_</sub> , V <sub>NO_</sub> , V <sub>NC_</sub>		E	V-		V+	V
On-Resistance	R <sub>ON</sub>	I <sub>COM_</sub> = 10mA, V <sub>NO_</sub> , V <sub>NC_</sub> = ±10V	+25°C		25	35	Ω
			E			45	
On-Resistance Match Between Channels (Note 4)	ΔR <sub>ON</sub>	I <sub>COM_</sub> = 10mA, V <sub>NO_</sub> , V <sub>NC_</sub> = ±10V	+25°C		0.2	1.5	Ω
			E			2.0	
On-Resistance Flatness	R <sub>FLAT(ON)</sub>	I <sub>COM_</sub> = 10mA, V <sub>NO_</sub> , V <sub>NC_</sub> = ±5V, 0	+25°C		1.0	3	Ω
			E			4	
NO <sub>-</sub> , NC <sub>-</sub> Off-Leakage Current (Note 5)	I <sub>NO_(OFF)</sub> , I <sub>NC_(OFF)</sub>	V <sub>COM_</sub> = ±10V, V <sub>NO_</sub> , V <sub>NC_</sub> = > 10V	+25°C	-0.25	+0.025	+0.25	nA
			E	-20		+20	
COM <sub>-</sub> Off-Leakage Current (Note 5)	I <sub>COM_(OFF)</sub>	V <sub>COM_</sub> = ±10V, V <sub>NO_</sub> , V <sub>NC_</sub> = > 10V	+25°C	-0.25	+0.025	+0.25	nA
			E	-20		+20	
COM <sub>-</sub> On-Leakage Current (Note 5)	I <sub>COM_(ON)</sub>	V <sub>COM_</sub> = ±10V, V <sub>NO_</sub> , V <sub>NC_</sub> = ±10V or floating	+25°C	-0.5	+0.025	+0.5	nA
			E	-40		+40	
FAULT							
Fault-Protected Analog Signal Range	V <sub>COM_</sub> , V <sub>NO_</sub> , V <sub>NC_</sub>	V+ = +15V, V- = -15V	E	-36		+36	V
		V+ = 0, V- = -15V	E	-36		+36	
		V+ = V- = 0	E	-40		+40	
NO <sub>-</sub> or NC <sub>-</sub> Off-Leakage Current	I <sub>NO_</sub> , I <sub>NC_</sub>	V <sub>NO_</sub> , V <sub>NC_</sub> = ±36V	+25°C	-1		+1	μA
			E	-10		+10	
COM <sub>-</sub> Off-Leakage Current	I <sub>COM_</sub>	V <sub>COM_</sub> = ±36V	+25°C	-1		+1	μA
			E	-10		+10	

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DG411F/DG412F/DG413F

## ELECTRICAL CHARACTERISTICS—±15V Dual Supplies (continued)

(V+ = +15V, V- = -15V, VIH = +2.4V, VIL = +0.8V, GND = 0, TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Notes 2, 3)

PARAMETER	SYMBOL	CONDITIONS	TA	MIN	TYP	MAX	UNITS
NO_ or NC_ Leakage Current	INO_, INC_	VNO_, VNC_ = ±40V, V+ = V- = 0	+25°C	-1		+1	μA
			E	-10		+10	
COM_ Leakage Current	ICOM_	VCOM_ = ±40V, V+ = V- = 0	+25°C	-1		+1	μA
			E	-10		+10	
NO_ or NC_ Off-Leakage Current	INO_, INC_	V+ = 0, V- = -15V, VNO_, VNC_ = ±36V	+25°C	-1		+1	μA
			E	-10		+10	
COM_ Off-Leakage Current	ICOM_	V+ = 0, V- = -15V, VCOM_ = ±36V	+25°C	-1		+1	μA
			E	-10		+10	
Fault-Trip Threshold			E	V- - 0.4		V+ + 0.4	V
± Fault Output Turn-Off Delay		VNO_, VNC_ = ±36V, RL = 1kΩ	E		20		ns
± Fault Recovery Time		VNO_, VNC_ = ±36V, RL = 1kΩ	E		1		μs
<b>SWITCH DYNAMICS</b>							
Turn-On Time	tON	VNO_ or VNC_ = ±10V, RL = 300Ω, CL = 35pF, Figure 2	+25°C		70	175	ns
			E			220	
Turn-Off Time	tOFF	VNO_ or VNC_ = ±10V, RL = 300Ω, CL = 35pF, Figure 2	+25°C		55	145	ns
			E			160	
Break-Before-Make Time Delay (DG413F only) (Note 6)	tBBM	VNO_ or VNC_ = ±10V, RL = 100Ω, CL = 10pF, Figure 3	+25°C	2	15		ns
			E	1			
Charge Injection	Q	VGEN = 0, RGEN = 0, CL = 1nF, Figure 4	+25°C		5		pC
NO_ or NC_ Off-Capacitance	CN_(OFF)	f = 1MHz, Figure 5	+25°C		15		pF
COM_ Off-Capacitance	CCOM_(OFF)	f = 1MHz, Figure 5	+25°C		15		pF
COM_ On-Capacitance	CCOM_(ON)	f = 1MHz, Figure 5	+25°C		47		pF
Off-Isolation (Note 7)	VISO	f = 1MHz, RL = 50Ω, CL = 15pF, PIN = 0dBm, Figure 6	+25°C		-65		dB
Channel-to-Channel Crosstalk (Note 8)	VCT	f = 1MHz, RL = 50Ω, CL = 15pF, PIN = 0dBm, Figure 6	+25°C		-105		dB
<b>LOGIC INPUT</b>							
Input Logic High	VIH		E	2.4			V
Input Logic Low	VIL		E			0.8	V
Input Leakage Current	IIN	VIN_ = 0 or V+	E	-1		+1	μA
<b>POWER SUPPLY</b>							
Power-Supply Range	V+, V-		E	±4.5		±20	V
V+ Supply Current	I+	All VIN_ = +5V, VCOM_ = 0	+25°C		355	600	μA
			E			800	
		All VIN_ = 0 or V+, VCOM_ = 0	+25°C		155	300	
			E			400	

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## ELECTRICAL CHARACTERISTICS—±15V Dual Supplies (continued)

(V+ = +15V, V- = -15V, VIH = +2.4V, VIL = +0.8V, GND = 0, TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Notes 2, 3)

PARAMETER	SYMBOL	CONDITIONS	TA	MIN	TYP	MAX	UNITS
V- Supply Current	I-	All VIN_ = +5V, VCOM_ = 0	+25°C		155	250	μA
			E			325	
		All VIN_ = 0 or V+, VCOM_ = 0	+25°C		155	250	
			E			325	
GND Supply Current	IGND	All VIN_ = +5V, VCOM_ = 0	+25°C		200	350	μA
			E			475	
		All VIN_ = 0 or V+, VCOM_ = 0	+25°C		0.1	1	
			E			10	

## ELECTRICAL CHARACTERISTICS—Single +12V Supply

(V+ = +12V, V- = 0, VIH = +2.4V, VIL = +0.8V, GND = 0, TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.) (Notes 2, 3)

PARAMETER	SYMBOL	CONDITIONS	T <sub>A</sub>	MIN	TYP	MAX	UNITS
ANALOG SWITCH							
Fault-Free Analog Signal Range	V <sub>COM_</sub> , V <sub>NO_</sub> , V <sub>NC_</sub>		E	0		V+	V
On-Resistance	R <sub>ON</sub>	I <sub>COM_</sub> = 1mA, V <sub>NO_</sub> , V <sub>NC_</sub> = +10V	+25°C		56	85	Ω
			E			120	
On-Resistance Match Between Channels (Note 4)	ΔR <sub>ON</sub>	I <sub>COM_</sub> = 1mA, V <sub>NO_</sub> , V <sub>NC_</sub> = +10V	+25°C		1.0	4	Ω
			E			5	
NO <sub>-</sub> , NC <sub>-</sub> Off-Leakage Current (Note 5)	I <sub>NO(OFF)</sub> , I <sub>NC(OFF)</sub>	V <sub>COM_</sub> = +1V, +10V, V <sub>NO_</sub> , V <sub>NC_</sub> = +10V, +1V	+25°C	-0.25		+0.25	nA
			E	-20		+20	
COM <sub>-</sub> Off-Leakage Current (Note 5)	I <sub>COM_</sub> (OFF)	V <sub>COM_</sub> = +1V, +10V, V <sub>NO_</sub> , V <sub>NC_</sub> = +10V, +1V	+25°C	-0.5		+0.25	nA
			E	-20		+20	
COM <sub>-</sub> On-Leakage Current (Note 5)	I <sub>COM_</sub> (ON)	V <sub>COM_</sub> = +1V, +10V, V <sub>NO_</sub> , V <sub>NC_</sub> = +1V, +10V, or floating	+25°C	-0.5		+0.5	nA
			E	-40		+40	
FAULT							
Fault-Protected Analog Signal Range	V <sub>COM_</sub> , V <sub>NO_</sub> , V <sub>NC_</sub>	Power on	E	-36		+36	V
		Power off	E	-40		+40	
NO <sub>-</sub> or NC <sub>-</sub> Off-Leakage Current (Note 5)	I <sub>NO_</sub> , I <sub>NC_</sub>	V <sub>NO_</sub> , V <sub>NC_</sub> = ±36V	+25°C	-1		+1	μA
			E	-10		+10	
COM <sub>-</sub> Off-Leakage Current (Note 5)	I <sub>COM_</sub>	V <sub>NO_</sub> , V <sub>NC_</sub> = ±36V	+25°C	-1		+1	μA
			E	-10		+10	
NO <sub>-</sub> or NC <sub>-</sub> Leakage Current (Note 5)	I <sub>NO_</sub> , I <sub>NC_</sub>	Supplies off, V <sub>NO_</sub> , V <sub>NC_</sub> = ±40V	+25°C	-1		+1	μA
			E	-10		+10	

# Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches

DG411F/DG412F/DG413F

## ELECTRICAL CHARACTERISTICS—Single +12V Supply (continued)

(V+ = +12V, V- = 0, V<sub>IH</sub> = +2.4V, V<sub>IL</sub> = +0.8V, GND = 0, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Notes 2, 3)

PARAMETER	SYMBOL	CONDITIONS	T <sub>A</sub>	MIN	TYP	MAX	UNITS
COM_ Leakage Current (Note 5)	I <sub>COM_</sub>	Supplies off, V <sub>NO_</sub> , V <sub>NC_</sub> = ±40V	+25°C	-1		+1	μA
			E	-10		+10	
+Fault Output Turn-Off Delay		V <sub>NO_</sub> , V <sub>NC_</sub> = +36V, R <sub>L</sub> = 1kΩ	E		20		ns
+Fault Recovery Time		V <sub>NO_</sub> , V <sub>NC_</sub> = +36V, R <sub>L</sub> = 1kΩ	E		1		μs
<b>SWITCH DYNAMICS</b>							
Turn-On Time	t <sub>ON</sub>	V <sub>NO_</sub> or V <sub>NC_</sub> = +10V, R <sub>L</sub> = 300Ω, C <sub>L</sub> = 35pF, Figure 2	+25°C		120	250	ns
			E			315	
Turn-Off Time	t <sub>OFF</sub>	V <sub>NO_</sub> or V <sub>NC_</sub> = +10V, R <sub>L</sub> = 300Ω, C <sub>L</sub> = 35pF, Figure 2	+25°C		70	125	ns
			E			140	
Break-Before-Make Time Delay (DG413F Only) (Note 6)	t <sub>BBM</sub>	V <sub>NO_</sub> or V <sub>NC_</sub> = +10V, R <sub>L</sub> = 100Ω, C <sub>L</sub> = 10pF, Figure 3	+25°C	2	50		ns
			E	1			
Charge Injection	Q	V <sub>GEN</sub> = 0, R <sub>GEN</sub> = 0, C <sub>L</sub> = 1nF, Figure 4	+25°C		5		pC
<b>LOGIC INPUT</b>							
Input Logic High	V <sub>IH</sub>		E	2.4			V
Input Logic Low	V <sub>IL</sub>		E			0.8	V
Input Leakage Current (Note 5)	I <sub>IN</sub>	V <sub>IN_</sub> = 0 or V+	E	-1		+1	μA
<b>POWER SUPPLY</b>							
Power-Supply Range	V+		E	+9		+36	V
V+ Supply Current	I+	All V <sub>IN_</sub> = +5V, V <sub>COM_</sub> = +6V	+25°C		180	350	μA
			E			450	
		All V <sub>IN_</sub> = 0 or V+, V <sub>COM_</sub> = +6V	+25°C		85	150	
			E			250	

**Note 2:** The algebraic convention is used in this data sheet; the most negative value is shown in the minimum column.

**Note 3:** Electrical specifications at -40°C are not production tested and guaranteed by design.

**Note 4:** ΔR<sub>ON</sub> = ΔR<sub>ON</sub>(MAX) - ΔR<sub>ON</sub>(MIN).

**Note 5:** Leakage parameters are 100% tested at maximum rated temperature and with dual supplies and guaranteed by design at +25°C.

**Note 6:** Guaranteed by design.

**Note 7:** Off-Isolation = 20 log<sub>10</sub> [V<sub>COM</sub>/(V<sub>NC</sub> or V<sub>NO</sub>)], V<sub>COM</sub> = output, V<sub>NC</sub> or V<sub>NO</sub> = input to off switch.

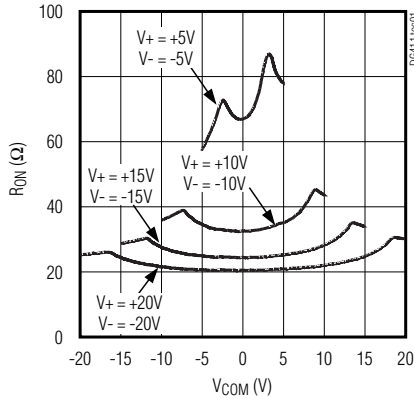
**Note 8:** Between any two switches.

# Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches

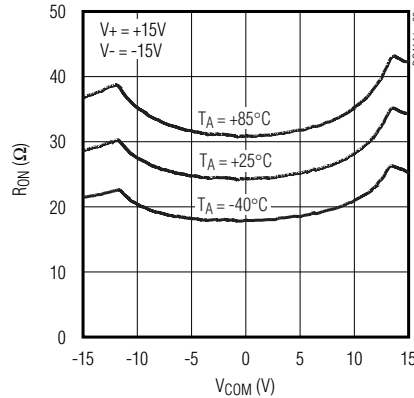
## Typical Operating Characteristics

( $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

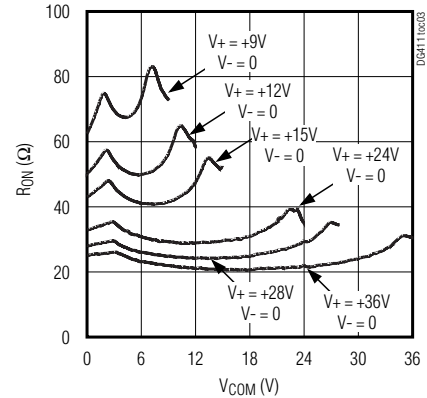
**ON-RESISTANCE vs.  $V_{\text{COM}}$  (DUAL SUPPLIES)**



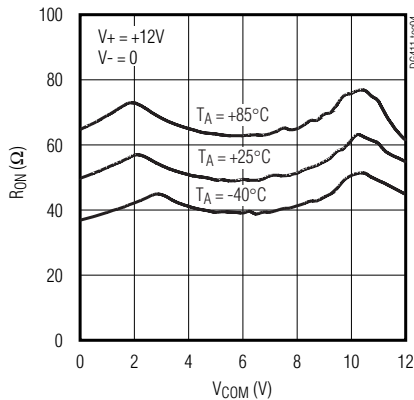
**ON-RESISTANCE vs.  $V_{\text{COM}}$  AND TEMPERATURE (DUAL SUPPLIES)**



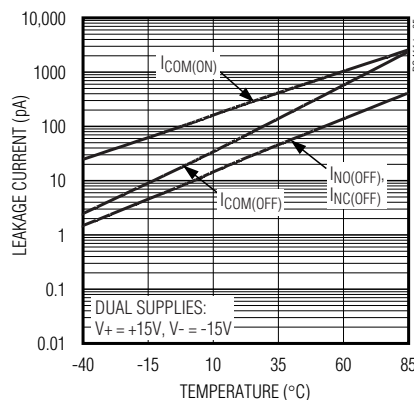
**ON-RESISTANCE vs.  $V_{\text{COM}}$  (SINGLE SUPPLY)**



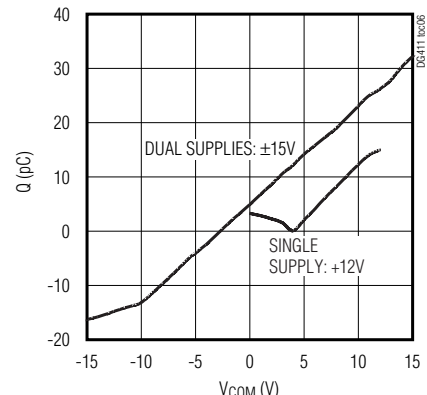
**ON-RESISTANCE vs.  $V_{\text{COM}}$  AND TEMPERATURE (SINGLE SUPPLY)**



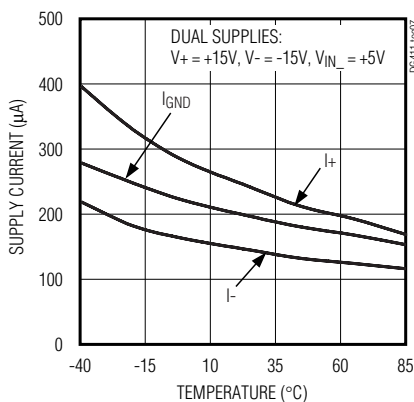
**ON/OFF-LEAKAGE CURRENT vs. TEMPERATURE**



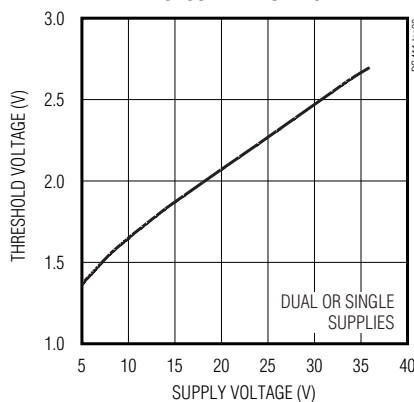
**CHARGE INJECTION vs.  $V_{\text{COM}}$**



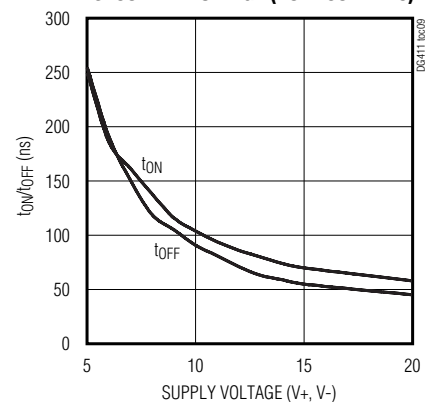
**SUPPLY CURRENT vs. TEMPERATURE**



**LOGIC-LEVEL THRESHOLD VOLTAGE vs. SUPPLY VOLTAGE**



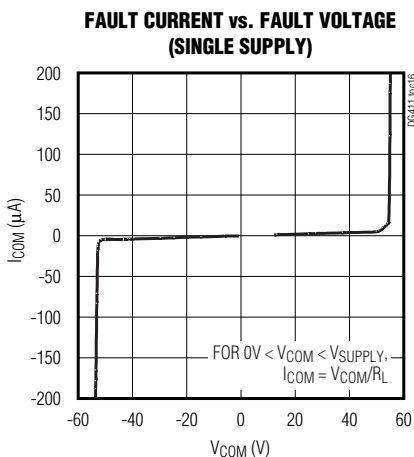
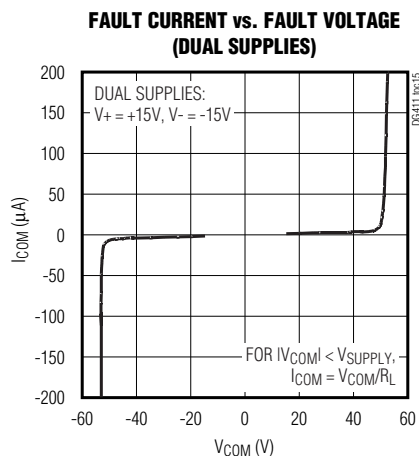
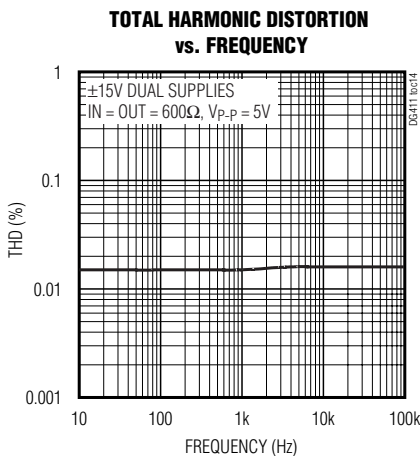
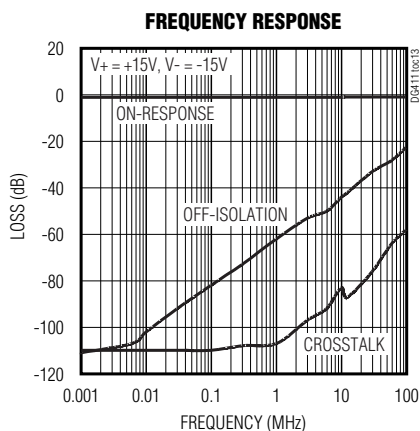
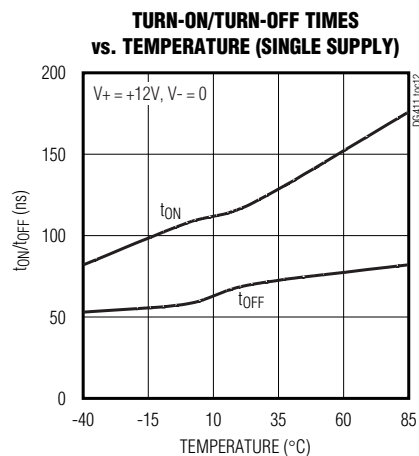
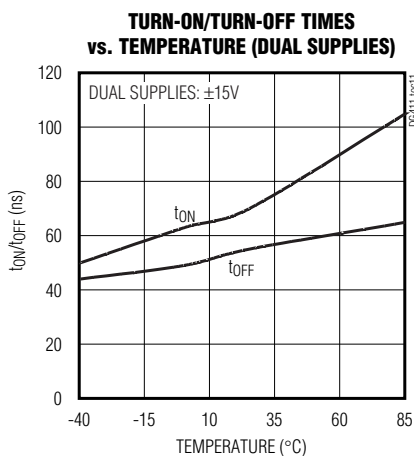
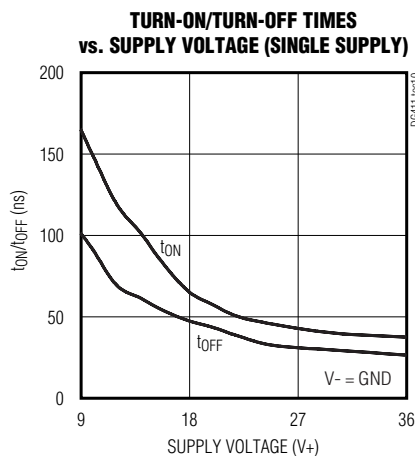
**TURN-ON/TURN-OFF TIMES vs. SUPPLY VOLTAGE (DUAL SUPPLIES)**



# Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches

## Typical Operating Characteristics (continued)

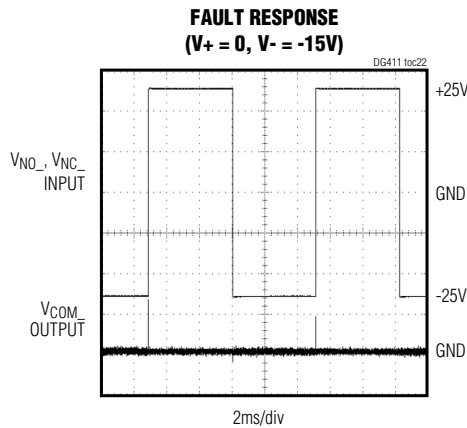
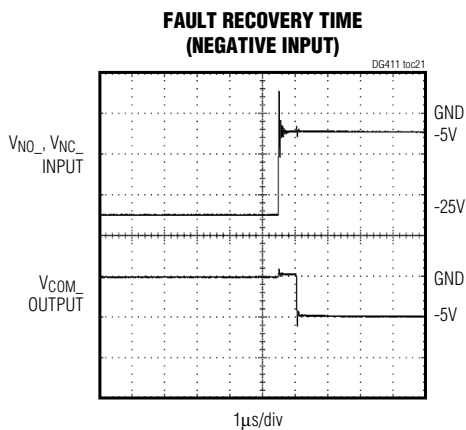
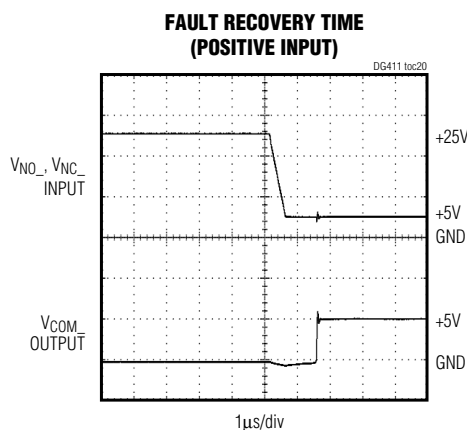
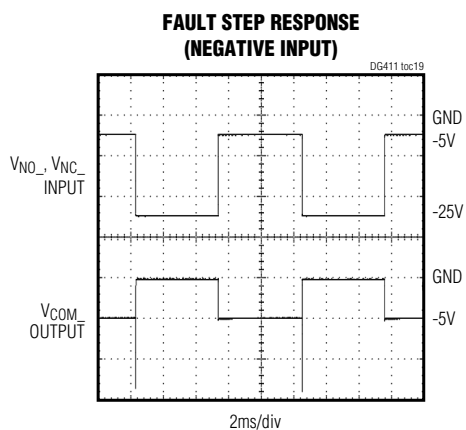
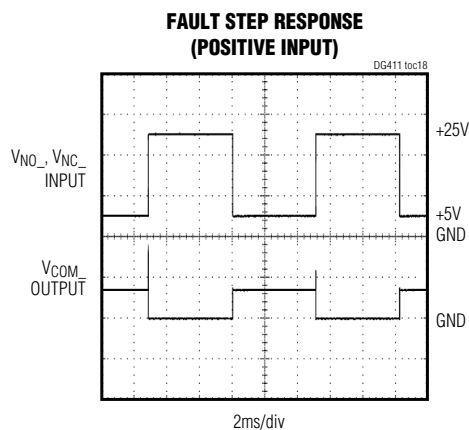
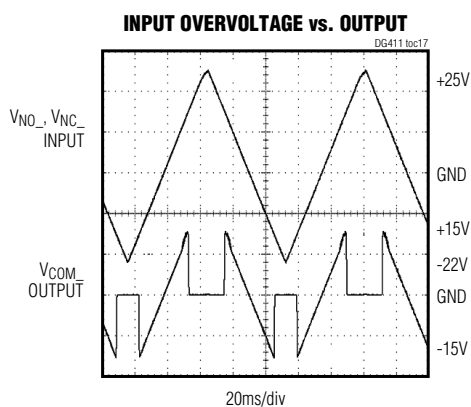
( $T_A = +25^\circ\text{C}$ , unless otherwise noted.)



# Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches

## Typical Operating Characteristics (continued)

( $T_A = +25^\circ\text{C}$ , unless otherwise noted.)





# Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches

## Pin Description

PIN			NAME	FUNCTION
DG411F	DG412F	DG413F		
1, 16, 9, 8	1, 16, 9, 8	1, 16, 9, 8	IN1, IN2, IN3, IN4	Logic Control Digital Inputs
2, 15, 10, 7	2, 15, 10, 7	2, 15, 10, 7	COM1, COM2, COM3, COM4	Analog Switch Common Terminals
3, 14, 11, 6	—	—	NC1, NC2, NC3, NC4	Analog Switch Normally Closed Terminals
—	3, 14, 11, 6	—	NO1, NO2, NO3, NO4	Analog Switch Normally Open Terminals
—	—	3, 6	NO1, NO4	Analog Switch Normally Open Terminals
—	—	14, 11	NC2, NC3	Analog Switch Normally Closed Terminals
4	4	4	V-	Negative-Supply Voltage Input. Connect to GND for single-supply operation. Bypass with a 0.1μF capacitor to GND.
5	5	5	GND	Ground. Connect to digital ground.
12	12	12	N.C.	No Connection. Not internally connected.
13	13	13	V+	Positive-Supply Voltage Input. Bypass with a 0.1μF capacitor to GND.

## Detailed Description

The DG411F/DG412F/DG413F are fault-protected CMOS analog switches with unique operation and construction. These switches differ considerably from traditional fault-protection switches, with several advantages. First, they are constructed with two parallel FETs, allowing very low on-resistance when the switch is on. Second, they allow signals on the NO\_ or NC\_ pins that are within, or slightly beyond, the supply rails to be passed through the switch to the COM\_ terminal (or vice versa), allowing true rail-to-rail signal operation. Third, the DG411F/DG412F/DG413F have the same fault-protection performance on any of the NO\_, NC\_, or COM\_ switch inputs. Operation is identical for both fault polarities. The fault protection extends to ±36V from GND with ±15V supplies.

During a fault condition, the particular overvoltage input (COM\_, NO\_, NC\_) pin becomes high impedance regardless of the switch state or load resistance. When power is removed, the fault protection is still in effect. In this case, the COM\_, NO\_, or NC\_ terminals are a virtual open circuit. The fault can be up to ±40V with power off. The switches turn off when V+ is not powered, regardless of V-.

### Pin Compatibility

These switches have identical pinouts to common non-fault-protected CMOS switches. They allow for carefree

direct replacement in existing printed circuit boards since the NO\_, NC\_, and COM\_ pins of each switch are fault protected.

### Internal Construction

Internal construction is shown in Figure 1, with the analog signal paths shown in bold. A single NO switch is shown. The NC configuration is identical except the logic-level translator becomes an inverter. The analog switch is formed by the parallel combination of N-channel FET (N1) and P-channel FET (P1), which are driven on and off simultaneously according to the input fault condition and the logic-level state.

### Normal Operation

Two comparators continuously compare the voltage on the COM\_, NO\_, and NC\_ pins with V+ and V-. When the signal on COM\_, NO\_, or NC\_ is between V+ and V-, the switch acts normally, with FETs N1 and P1 turning on and off in response to IN\_ signals. The parallel combination of N1 and P1 forms a low-value resistor between NO\_ (or NC\_) and COM\_ so that signals pass equally well in either direction.

### Positive Fault Condition

When the signal on NO\_ (or NC\_) and COM\_ exceeds V+ by about 50mV, the high-fault comparator output is high, turning off FETs N1 and P1. This makes the NO\_ (or NC\_) and COM\_ pins high impedance regardless of

# Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches

the switch state. If the switch state is off, all FETs are turned off and both NO\_ (or NC\_) and COM\_ are high impedance.

## Negative Fault Condition

When the signal on NO\_ (or NC\_) and COM\_ exceeds V- by about 50mV, the low-fault comparator output is high, turning off FETs N1 and P1. This makes the NO\_ (or NC\_) and COM\_ pins high impedance regardless of the switch state. If the switch state is off, all FETs are turned off and both NO\_ (or NC\_) and COM\_ are high impedance.

## Transient Fault Response and Recovery

When a fast rise-time and fall-time transient on NO\_, NC\_, or COM\_ exceeds V+ or V-, the output follows the input to the supply rail with only a few nanoseconds delay. This delay is due to the switch on-resistance and circuit capacitance to ground. When the input transient returns to within the supply rails, however, there is a longer output recovery time delay. For positive faults, the recovery time is typically 1μs. For negative faults, the recovery time is typically 0.5μs. These values depend on the output resistance and capacitance, and are not production tested or guaranteed. The delays are not dependent on the fault amplitude. Higher load resistance and capacitance increase recovery times.

## Fault-Protection Voltage and Power Off

The maximum fault voltage on the NO\_ (or NC\_) and COM\_ pins is ±36V with power applied and ±40V with power off.

## Failure Modes

Exceeding the fault-protection voltage limits on NO\_, NC\_, or COM\_, even for very short periods, can cause the device to fail. See the *Absolute Maximum Ratings*. The failure modes may not be obvious, and failure in one switch may or may not affect other switches in the same package.

## Ground

There is no galvanic connection between the analog signal paths and GND. The analog signal paths consist of an N-channel and P-channel MOSFET with their sources and drains paralleled and their gates driven out of phase to V+ and V- by the logic-level translators. However, the potential of the analog signals must be defined or at least limited with respect to GND.

V+ and GND power the internal logic and logic-level translators and set the input logic thresholds. The logic-level translators convert the logic levels to switched V+ and V- signals to drive the gates of the analog switches. This drive signal is the only connection between the power supplies and the analog signals.

## IN\_ Logic-Level Thresholds

The logic-level thresholds are CMOS and TTL compatible when V+ is +15V. As V+ is raised, the threshold increases slightly, and when V+ reaches 25V, the level threshold is about 2.3V, above the TTL output high-level minimum of 2.4V, but still compatible with CMOS outputs (see the *Typical Operating Characteristics*). V- has no effect on the logic-level thresholds.

## Bipolar Supplies

The DG411F/DG412F/DG413F operate with bipolar supplies between ±4.5V and ±20V. The V+ and V- supplies need not be symmetrical, but their difference cannot exceed the absolute maximum rating of 44V.

## Single Supply

The DG411F/DG412F/DG413F operate from a single supply between +9V and +36V when V- is connected to GND.

## Ordering Information (continued)

PART	TEMP RANGE	PIN-PACKAGE
DG412FEUE	-40°C to +85°C	16 TSSOP
DG412FDY	-40°C to +85°C	16 SO
DG412FDJ	-40°C to +85°C	16 Plastic DIP
DG413FEUE	-40°C to +85°C	16 TSSOP
DG413FDY	-40°C to +85°C	16 SO
DG413FDJ	-40°C to +85°C	16 Plastic DIP

## Chip Information

TRANSISTOR COUNT: 251

PROCESS: CMOS

SUBSTRATE CONNECTED TO: V+

# Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches

## Test Circuits/Timing Diagrams

DG411F/DG412F/DG413F

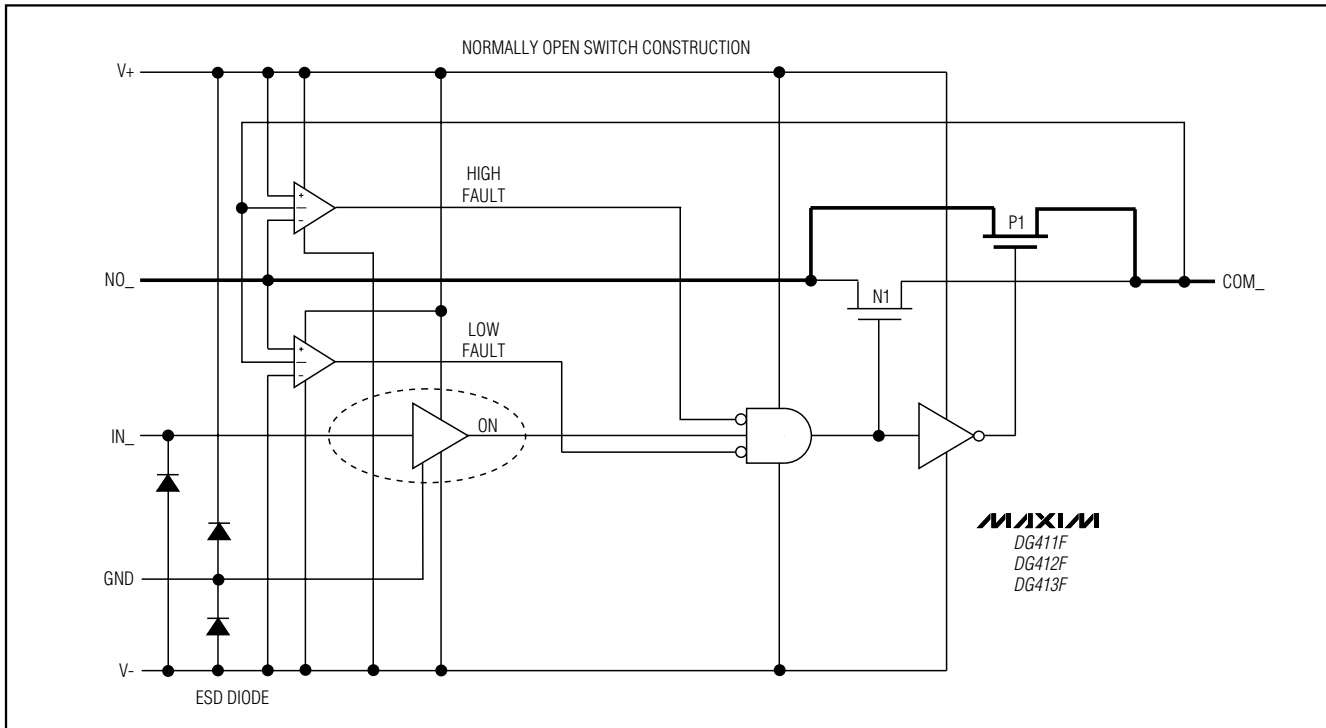


Figure 1. Functional Diagram

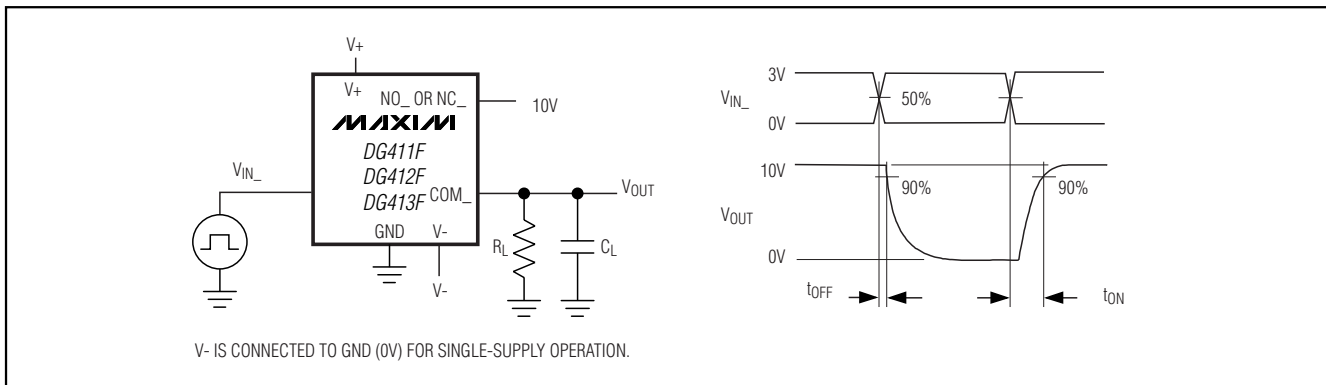


Figure 2. Switch Turn-On/Turn-Off Times

# Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches

## Test Circuits/Timing Diagrams (continued)

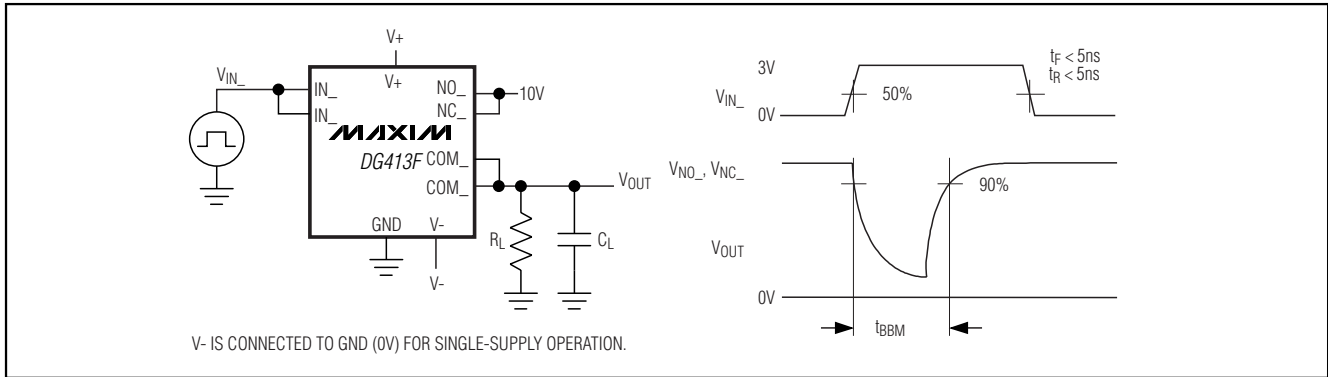


Figure 3. DG413F Break-Before-Make Interval

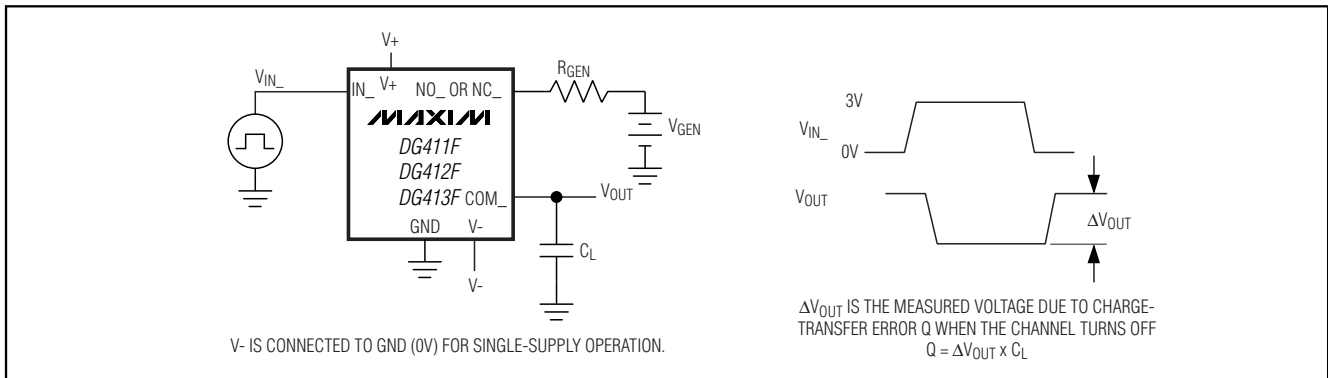


Figure 4. Charge Injection

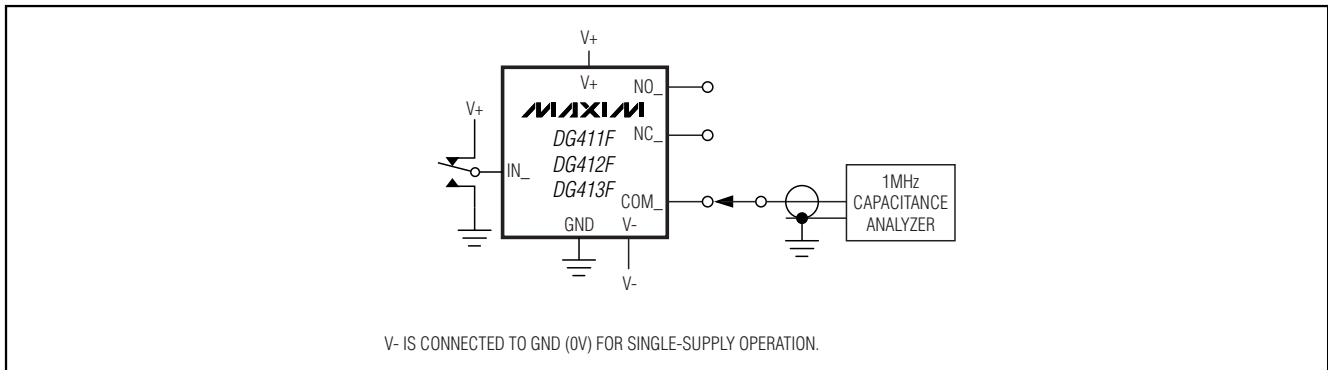


Figure 5. COM, NO, NC Capacitance

# Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches

## Test Circuits/Timing Diagrams (continued)

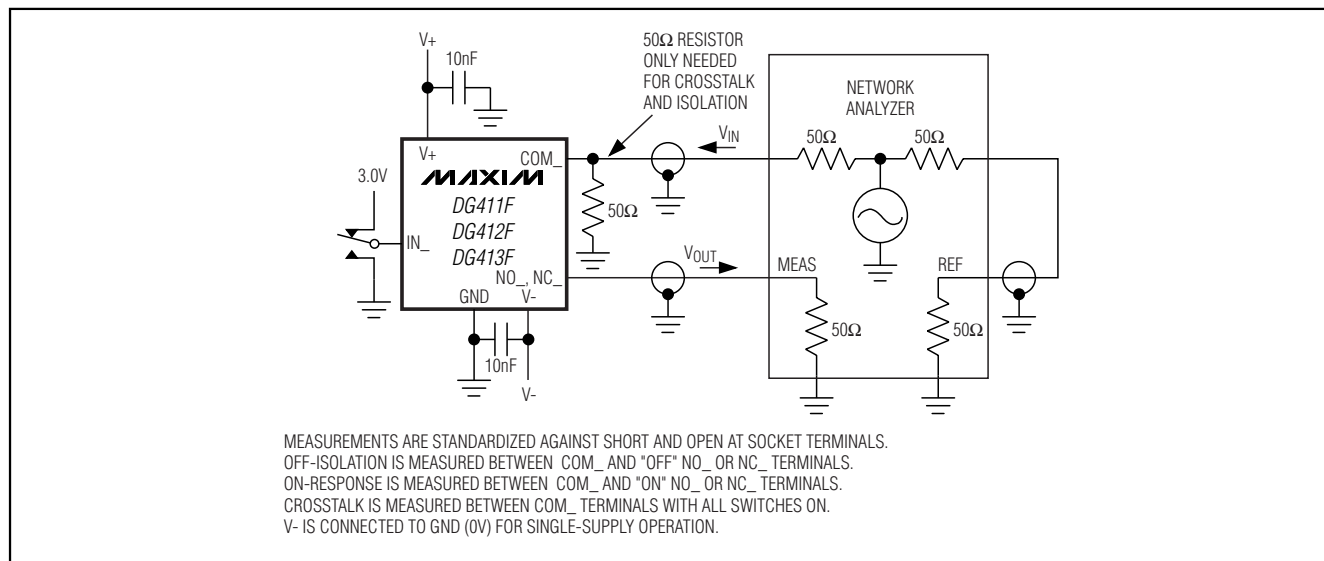
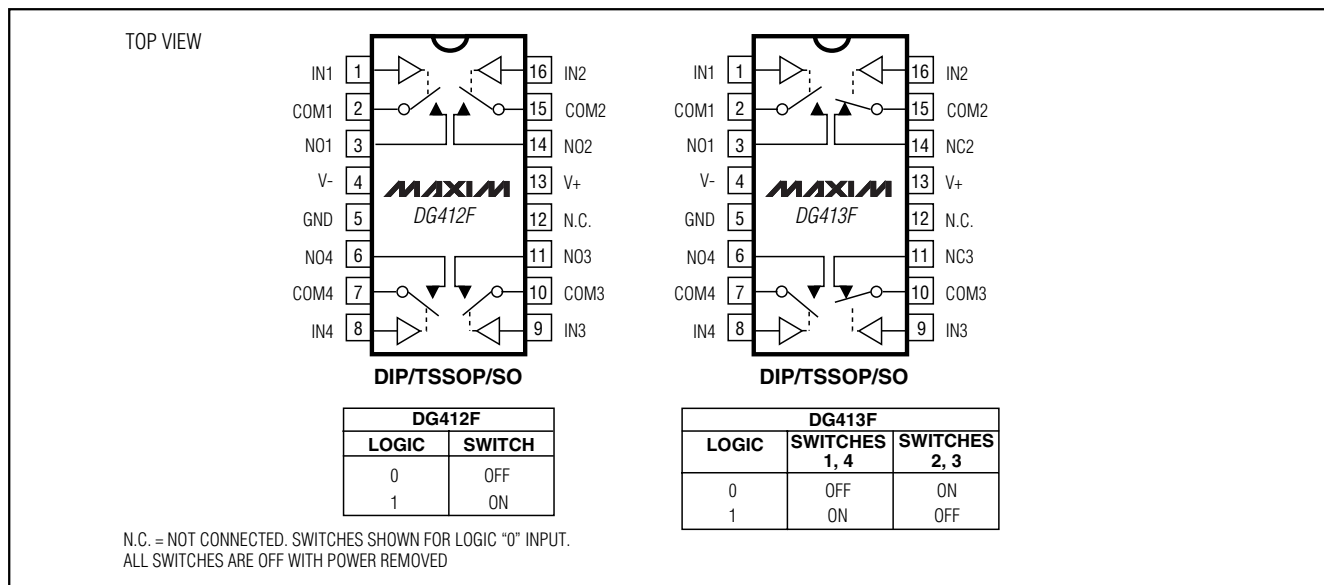


Figure 6. Frequency Response, Off-Isolation, and Crosstalk

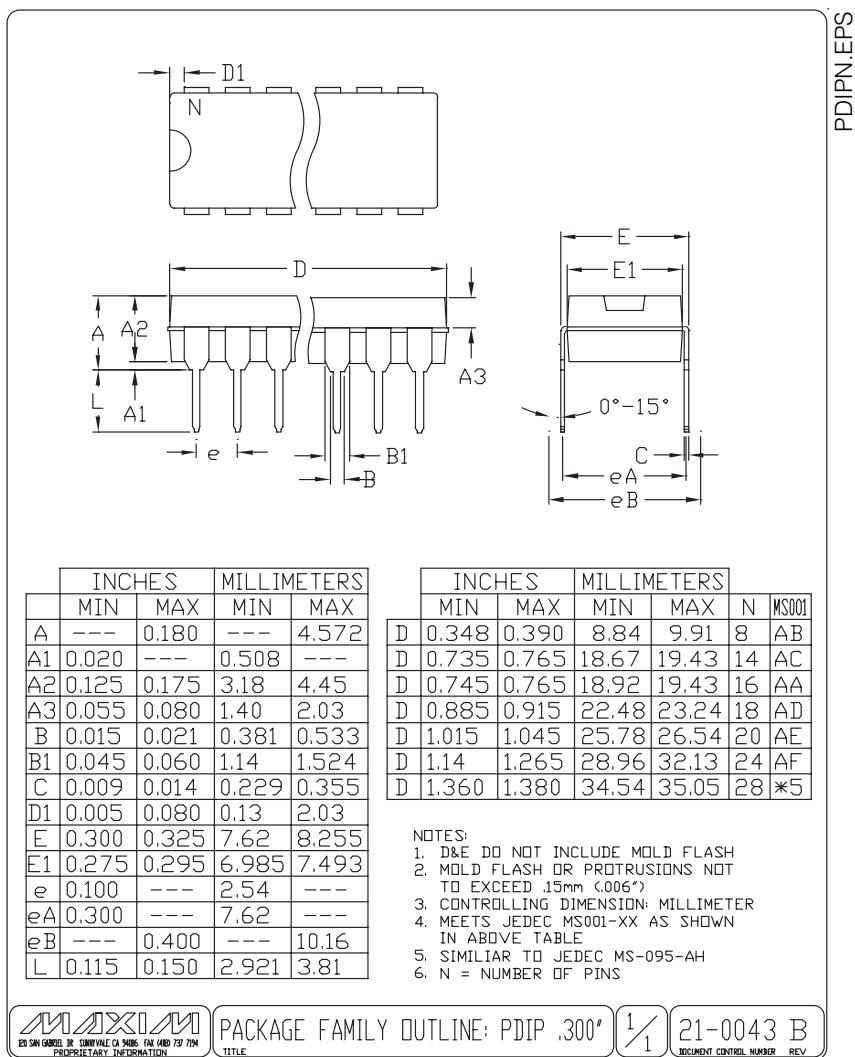
## Pin Configurations (continued)



# Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches

## Package Information

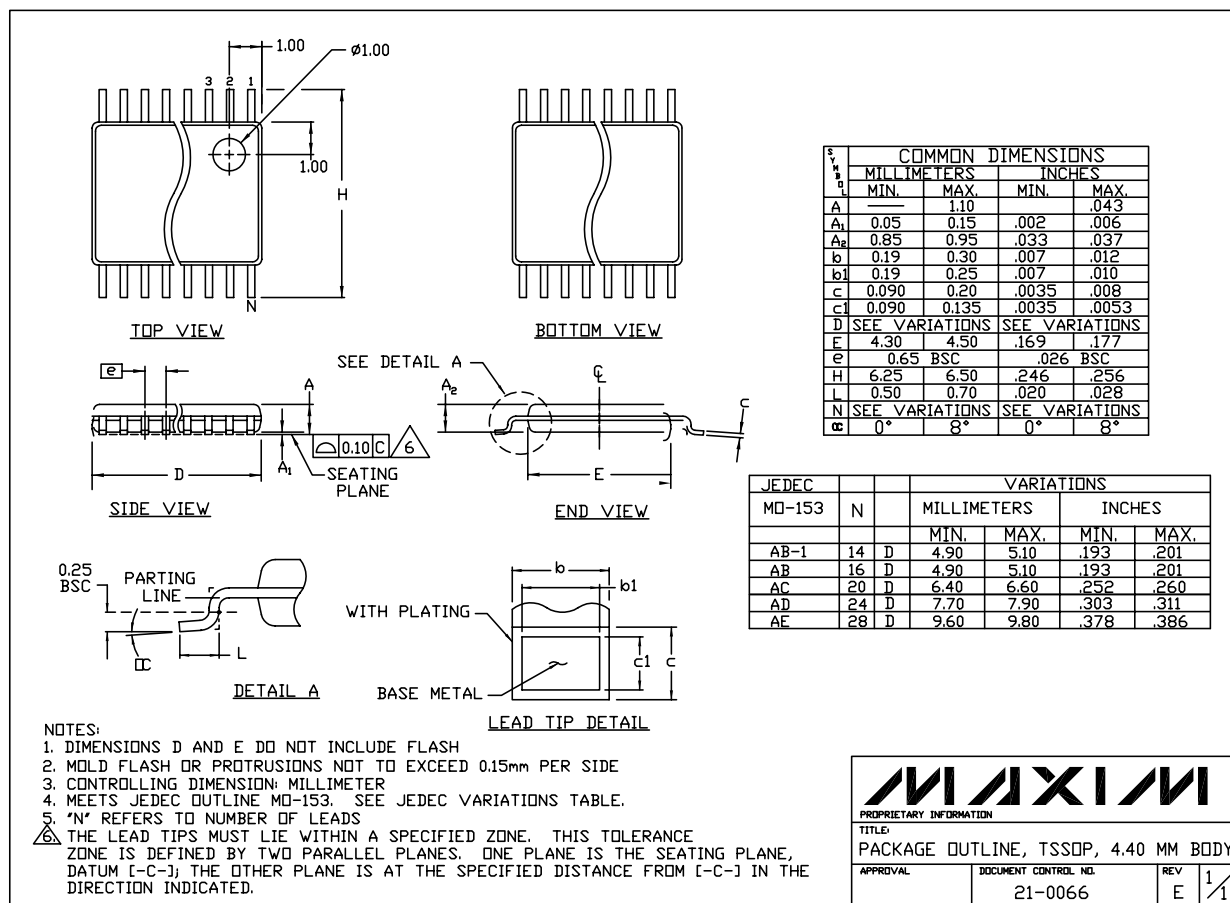
(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)



# Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches

## Package Information (continued)

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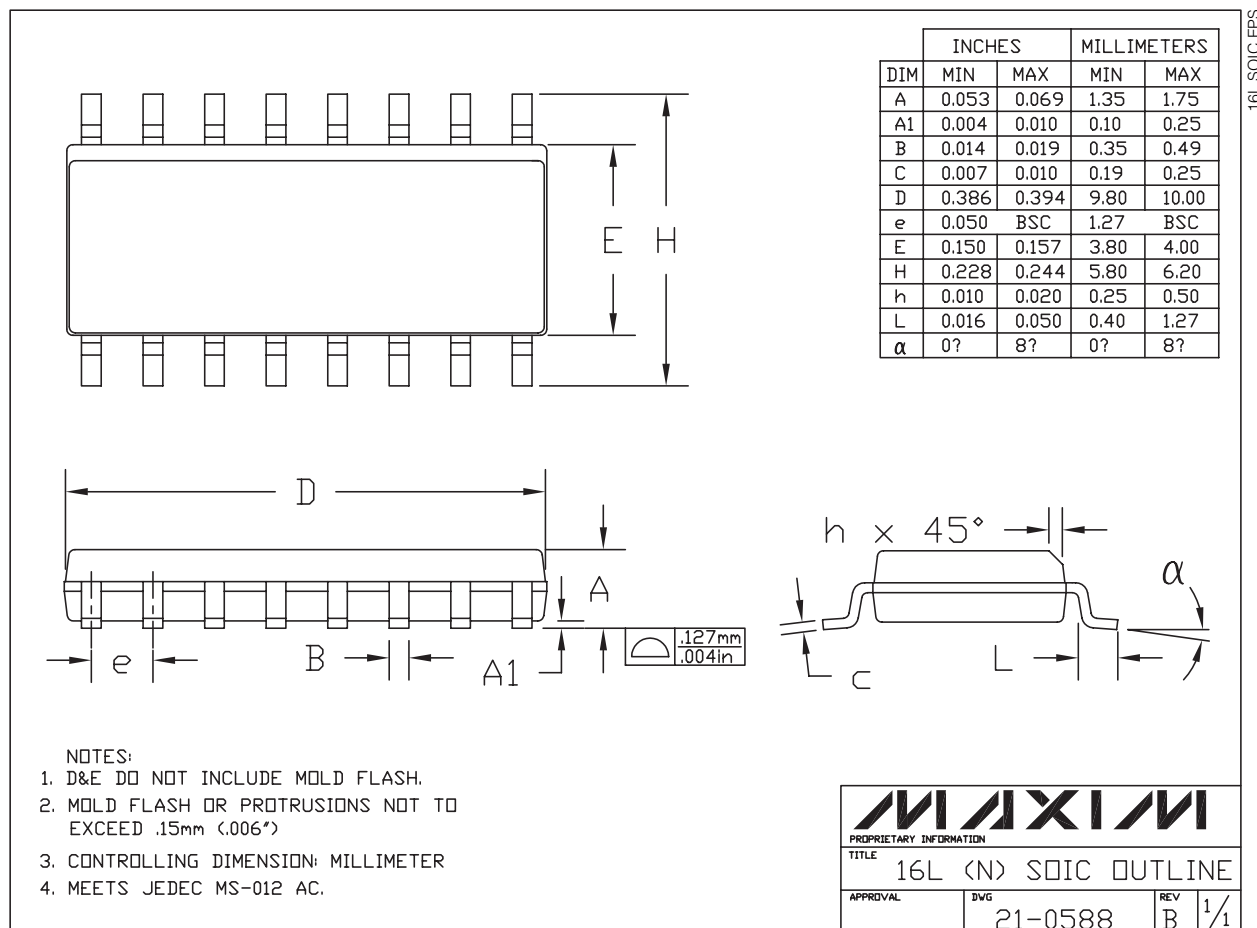
TSSOP, NO PADS/LEADS

DG411F/DG412F/DG413F

# Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches

## Package Information (continued)

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