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## DG411F/DG412F/ DG413F

## 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  $\pm 36\text{V}$  with power on and up to  $\pm 40\text{V}$  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  $+25^\circ\text{C}$ .

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  $\pm 4.5\text{V}$  to  $\pm 20\text{V}$  or a single supply between  $+9\text{V}$  and  $+36\text{V}$ . All digital inputs have  $+0.8\text{V}$  and  $+2.4\text{V}$  logic thresholds, ensuring both TTL and CMOS logic compatibility when using  $\pm 15\text{V}$  or a single  $+12\text{V}$  supply.

For supply voltages of  $\pm 5\text{V}$ ,  $+5\text{V}$ , and  $+3\text{V}$ , 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

### Benefits and 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
- $\pm 40\text{V}$  Fault Protection with Power Off
- $\pm 36\text{V}$  Fault Protection with  $\pm 15\text{V}$  Supplies
- Control Line Fault Protection from  $V_- - 0.3\text{V}$  to  $V_- + 40\text{V}$
- Pin Compatible with Industry-Standard DG411/DG412/DG413
- $20\text{ns}$  (typ) Fault Response Time
- $35\Omega$  (max)  $R_{\text{ON}}$  with  $\pm 15\text{V}$  Supplies
- $\pm 4.5\text{V}$  to  $\pm 20\text{V}$  Dual Supplies
- $+9\text{V}$  to  $+36\text{V}$  Single Supply
- TTL- and CMOS-Compatible Logic Inputs with  $\pm 15\text{V}$  or Single  $+9\text{V}$  to  $+15\text{V}$  Supplies

Ordering Information appears at end of data sheet.

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

## Absolute Maximum Ratings

(Voltages Referenced to GND)

V+ .....	-0.3V to +44V	Peak Current COM_, NO_, NC_ (pulsed at 1ms, 10% duty cycle) .....	±100mA
V- .....	-44V to +0.3V	Continuous Power Dissipation (T <sub>A</sub> = +70°C)	
V+ to V- .....	-0.3V to +44V	16-Pin TSSOP (derate 9.4mW/°C above +70°C) .....	755mW
IN_ .....	(V- - 0.3V) to (V- + 40V)	16-Pin SO (derate 8.7mW/°C above +70°C) .....	696mW
NO_, NC_ to COM_ (Note1) .....	-40V to +40V	16-Pin Plastic DIP (derate 10.53mW/°C above +70°C) .....	842mW
COM_, NO_, NC_ Voltage with Power On (Note 1) .....	-36V to +36V	Operating Temperature Range .....	-40°C to +85°C
COM_, NO_, NC_ Voltage with Power Off (Note 1) .....	-40V to +40V	Junction Temperature .....	+150°C
Continuous Current (any terminal) .....	±30mA	Storage Temperature Range .....	-65°C to +160°C
		Lead Temperature (soldering, 10s) .....	+300°C

**Note 1:** COM\_, NO\_, and NC\_ pins are fault protected. Signals on COM\_, NO\_, and NC\_ 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.*

## Package Information

<b>PACKAGE TYPE: SOIC</b>	
Outline Number	<a href="#">21-0041</a>
<b>PACKAGE TYPE: PDIP</b>	
Outline Number	<a href="#">21-0043</a>
<b>PACKAGE TYPE: TSSOP</b>	
Outline Number	<a href="#">21-0066</a>

For the latest package outline information and land patterns (footprints), go to [www.maximintegrated.com/packages](http://www.maximintegrated.com/packages). Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

# DG411F/DG412F/ DG413F

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

### Electrical Characteristics— ±15V Dual Supplies

(V+ = +15V, V- = -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_, NC_ 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	-30		+30	
COM_ 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	-30		+30	
COM_ 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 SignalRange	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_ or NC_ 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_ Off-Leakage Current	I <sub>COM_</sub>	V <sub>COM_</sub> = ±36V	+25°C	-1		+1	μA
			E	-10		+10	
NO_ or NC_ Leakage Current	I <sub>NO_</sub> , I <sub>NC_</sub>	V <sub>NO_</sub> , V <sub>NC_</sub> = ±40V, V+ = V- = 0	+25°C	-1		+1	μA
			E	-10		+10	
COM_ Leakage Current	I <sub>COM_</sub>	V <sub>COM_</sub> = ±40V, V+ = V- = 0	+25°C	-1		+1	μA
			E	-10		+10	
NO_ or NC_ Off-Leakage Current	I <sub>NO_</sub> , I <sub>NC_</sub>	V+ = 0, V- = -15V, V <sub>NO_</sub> , V <sub>NC_</sub> = ±36V	+25°C	-1		+1	μA
			E	-10		+10	
COM_ Off-Leakage Current	I <sub>COM_</sub>	V+ = 0, V- = -15V, V <sub>COM_</sub> = ±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		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
SWITCH DYNAMICS							
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	70	175		ns
			E		220		
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	55	145		ns
			E		160		

# DG411F/DG412F/ DG413F

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

### Electrical Characteristics— ±15V Dual Supplies (continued)

(V+ = +15V, V- = -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
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	15		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
NO_ or NC_ Off-Capacitance	C <sub>N_(OFF)</sub>	f = 1MHz, Figure 5	+25°C		15		pF
COM_ Off-Capacitance	C <sub>COM_(OFF)</sub>	f = 1MHz, Figure 5	+25°C		15		pF
COM_ On-Capacitance	C <sub>COM_(ON)</sub>	f = 1MHz, Figure 5	+25°C		47		pF
Off-Isolation (Note 7)	V <sub>ISO</sub>	f = 1MHz, R <sub>L</sub> = 50Ω, C <sub>L</sub> = 15pF, P <sub>IN</sub> = 0dBm, Figure 6	+25°C		-65		dB
Channel-to-Channel Crosstalk (Note 8)	V <sub>CT</sub>	f = 1MHz, R <sub>L</sub> = 50Ω, C <sub>L</sub> = 15pF, P <sub>IN</sub> = 0dBm, Figure 6	+25°C		-105		dB
<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	I <sub>IN</sub>	V <sub>IN_</sub> = 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 V <sub>IN_</sub> = +5V, V <sub>COM_</sub> = 0	+25°C		355	600	μA
			E			800	
		All V <sub>IN_</sub> = 0 or V+, V <sub>COM_</sub> = 0	+25°C		155	300	
			E			400	
V- Supply Current	I-	All V <sub>IN_</sub> = +5V, V <sub>COM_</sub> = 0	+25°C		155	250	μA
			E		325		
		All V <sub>IN_</sub> = 0 or V+, V <sub>COM_</sub> = 0	+25°C		155	250	
			E		325		
GND Supply Current	I <sub>GND</sub>	All V <sub>IN_</sub> = +5V, V <sub>COM_</sub> = 0	+25°C		200	350	μA
			E		475		
		All V <sub>IN_</sub> = 0 or V+, V <sub>COM_</sub> = 0	+25°C		0.1	1	
			E			10	

# DG411F/DG412F/ DG413F

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

### Electrical Characteristics— Single +12V Supply

(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
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> = 1mA, 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> = 1mA, V <sub>NO_</sub> , V <sub>NC_</sub> = +10V	+25°C	0.2	1.5		Ω
			E	2.0			
NO_, NC_ 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	+0.025	+0.25	nA
			E	-30		+30	
COM_ Off-Leakage Current (Note 5)	I <sub>COM_(OFF)</sub>	V <sub>COM_</sub> = +1V, +10V, V <sub>NO_</sub> , V <sub>NC_</sub> = +10V, +1V	+25°C	-0.25	+0.025	+0.25	nA
			E	-30		+30	
COM_ On-Leakage Current (Note 5)	I <sub>COM_(ON)</sub>	V <sub>COM_</sub> = +1V, +10V, V <sub>NO_</sub> , V <sub>NC_</sub> = +1V, +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>	Power on	E	-36		+36	V
		Power off	E	-40		+40	
NO_ or NC_ 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_ 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_ or NC_ 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	
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
SWITCH DYNAMICS							
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			

## Electrical Characteristics (continued)

( $V_+ = +12V$ ,  $V_- = 0$ ,  $V_{IH} = +2.4V$ ,  $V_{IL} = +0.8V$ ,  $GND = 0$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .) (Notes 2, 3)

PARAMETER	SYMBOL	CONDITIONS	$T_A$	MIN	TYP	MAX	UNITS
Charge Injection	Q	$V_{GEN} = 0$ , $R_{GEN} = 0$ , $C_L = 1nF$ , Figure 4	$+25^\circ C$		5		pC
<b>LOGIC INPUT</b>							
Input Logic High	$V_{IH}$		E	2.4			V
Input Logic Low	$V_{IL}$		E			0.8	V
Input Leakage Current (Note 5)	$I_{IN}$	$V_{IN} = 0$ or $V_+$	E	-1		+1	$\mu A$
<b>POWER SUPPLY</b>							
Power-Supply Range	$V_+$ , $V_-$		E	+9		+36	V
V+ Supply Current	$I_+$	All $V_{IN\_} = +5V$ , $V_{COM\_} = +6V$	$+25^\circ C$		180	350	$\mu A$
			E			450	
		All $V_{IN\_} = 0$ or $V_+$ , $V_{COM\_} = +6V$	$+25^\circ C$		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  $-40^\circ C$  are not production tested and guaranteed by design.

**Note 4:**  $\Delta R_{ON} = \Delta R_{ON(MAX)} - \Delta R_{ON(MIN)}$ .

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

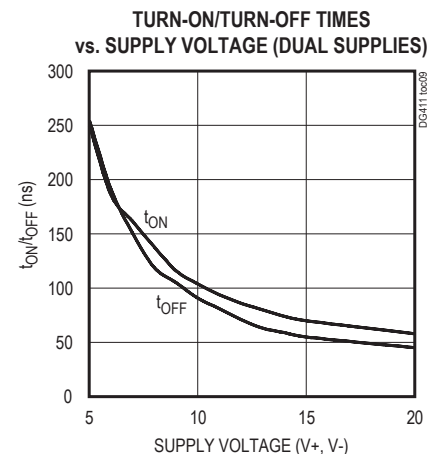
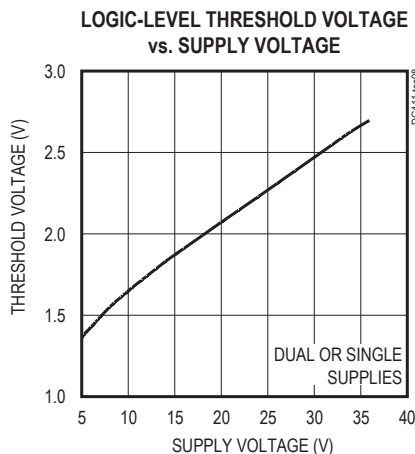
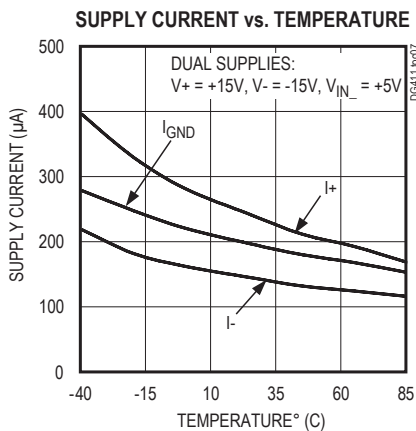
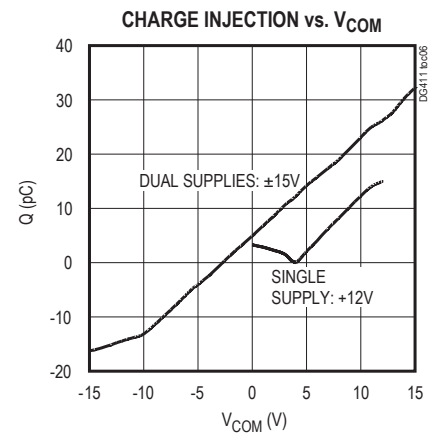
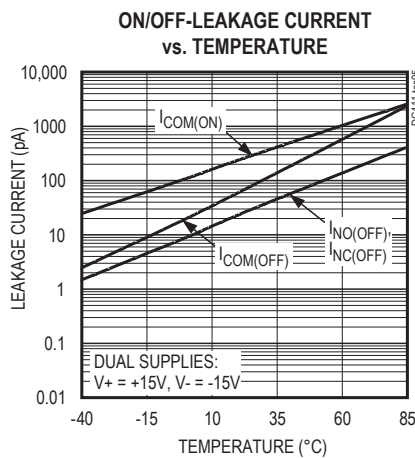
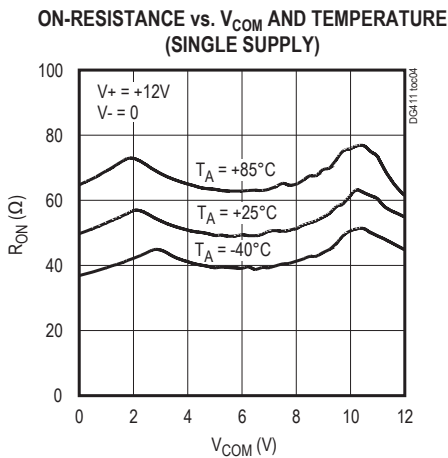
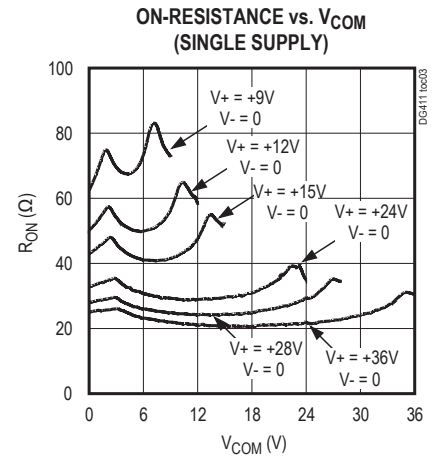
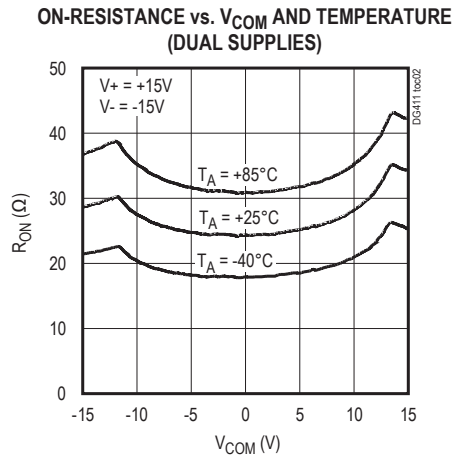
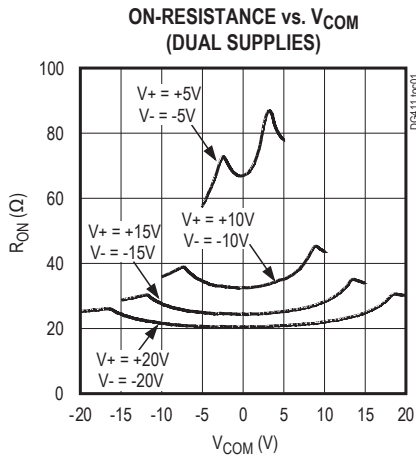
**Note 6:** Guaranteed by design.

**Note 7:** Off-Isolation =  $20 \log_{10} [V_{COM}/(V_{NC} \text{ or } V_{NO})]$ ,  $V_{COM}$  = output,  $V_{NC}$  or  $V_{NO}$  = input to off switch.

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

## Typical Operating Characteristics

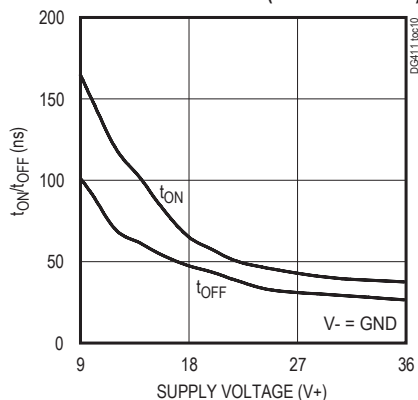
( $T_A = +25^\circ\text{C}$ , unless otherwise noted.)



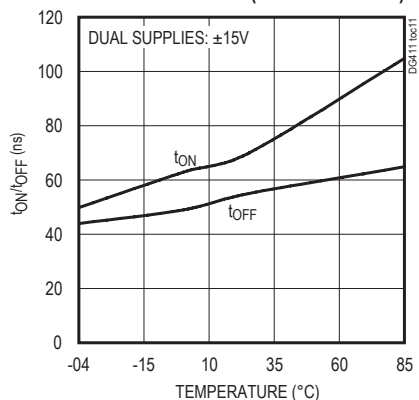
## Typical Operating Characteristics (continued)

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

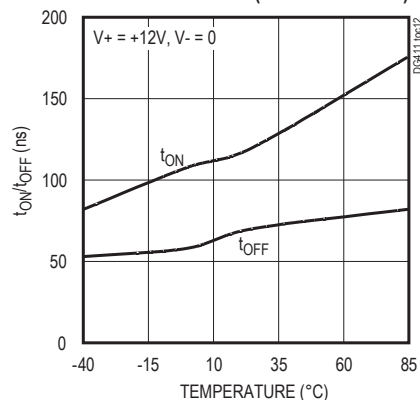
TURN-ON/TURN-OFF TIMES  
vs. SUPPLY VOLTAGE (SINGLE SUPPLY)



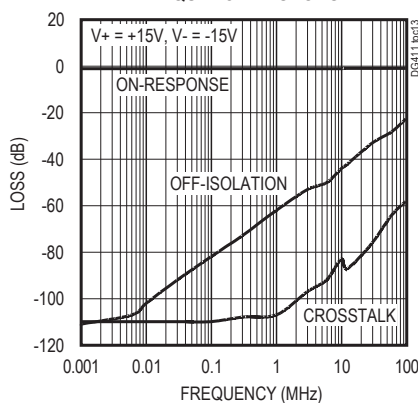
TURN-ON/TURN-OFF TIMES  
vs. TEMPERATURE (DUAL SUPPLIES)



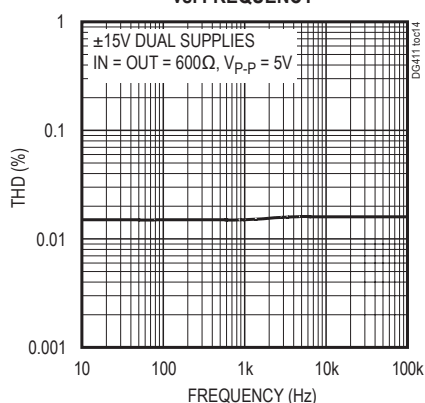
TURN-ON/TURN-OFF TIMES  
vs. TEMPERATURE (SINGLE SUPPLY)



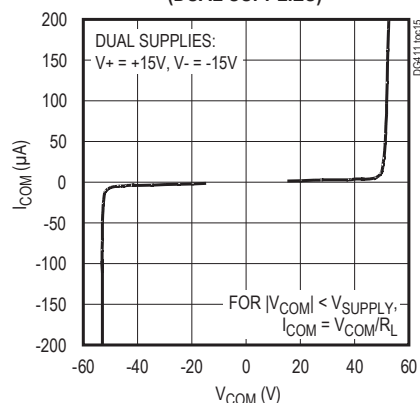
FREQUENCY RESPONSE



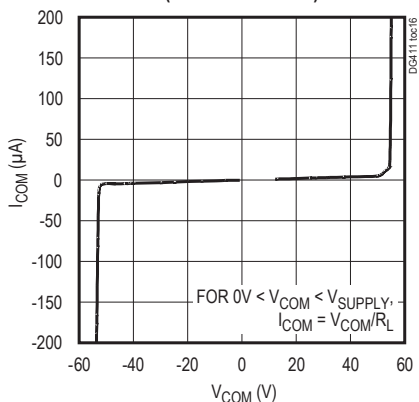
TOTAL HARMONIC DISTORTION  
vs. FREQUENCY



FAULT CURRENT vs. FAULT VOLTAGE  
(DUAL SUPPLIES)

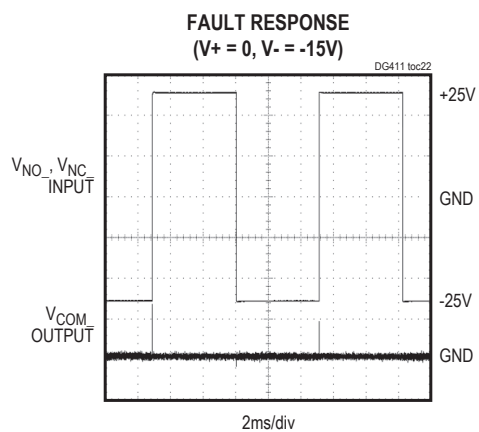
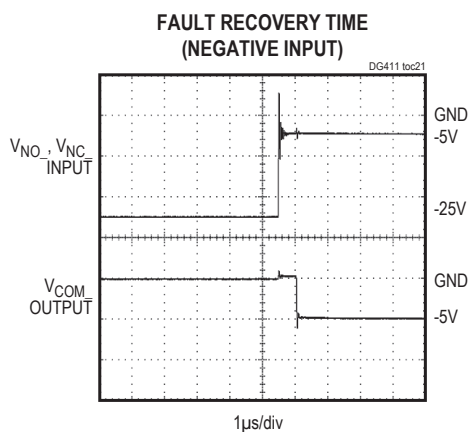
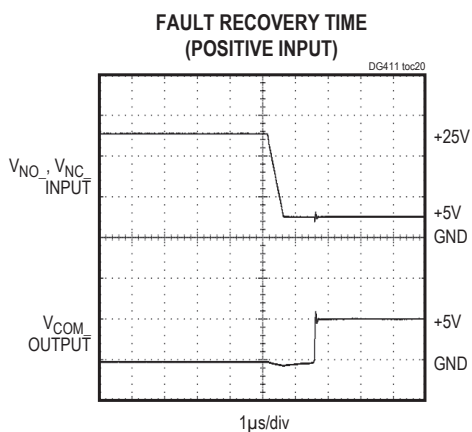
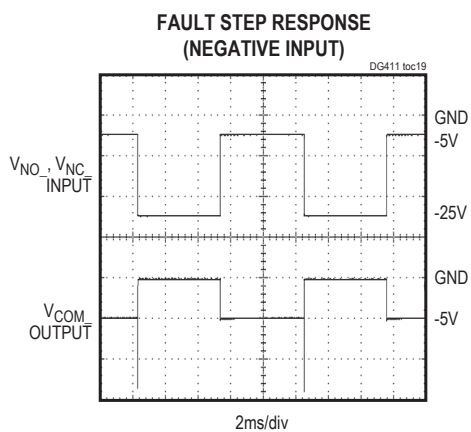
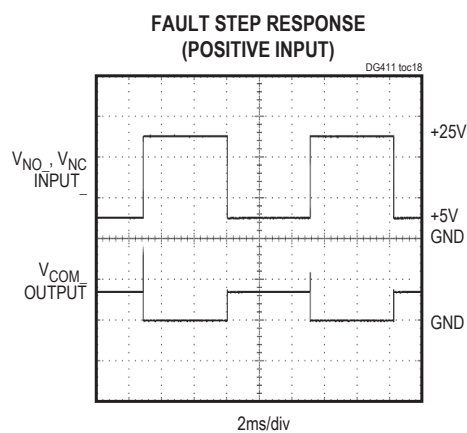
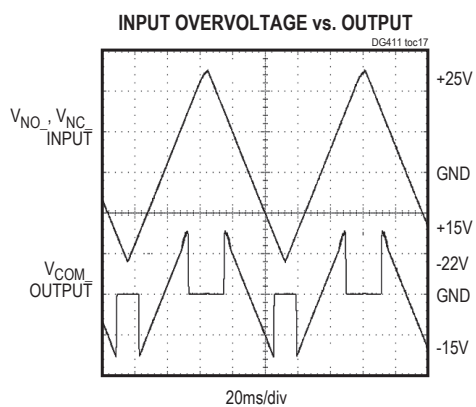


FAULT CURRENT vs. FAULT VOLTAGE  
(SINGLE SUPPLY)



## Typical Operating Characteristics (continued)

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



DG411F/DG412F/  
DG413F

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

Pin Configurations

TOP VIEW

DIP/TSSOP/SO

DG411F	
LOGIC	SWITCH
0	ON
1	OFF

N.C. = NOT CONNECTED. SWITCHES SHOWN FOR LOGIC 0 INPUT.  
ALL SWITCHES ARE OFF WITH POWER REMOVED.

TOP VIEW

DIP/TSSOP/SO

DG412F	
LOGIC	SWITCH
0	OFF
1	ON

DIP/TSSOP/SO

DG413F		
LOGIC	SWITCHES 1, 4	SWITCHES 2, 3
0	OFF	ON
1	ON	OFF

N.C. = NOT CONNECTED. SWITCHES SHOWN FOR LOGIC "0" INPUT.  
ALL SWITCHES ARE OFF WITH POWER REMOVED

## 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 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.

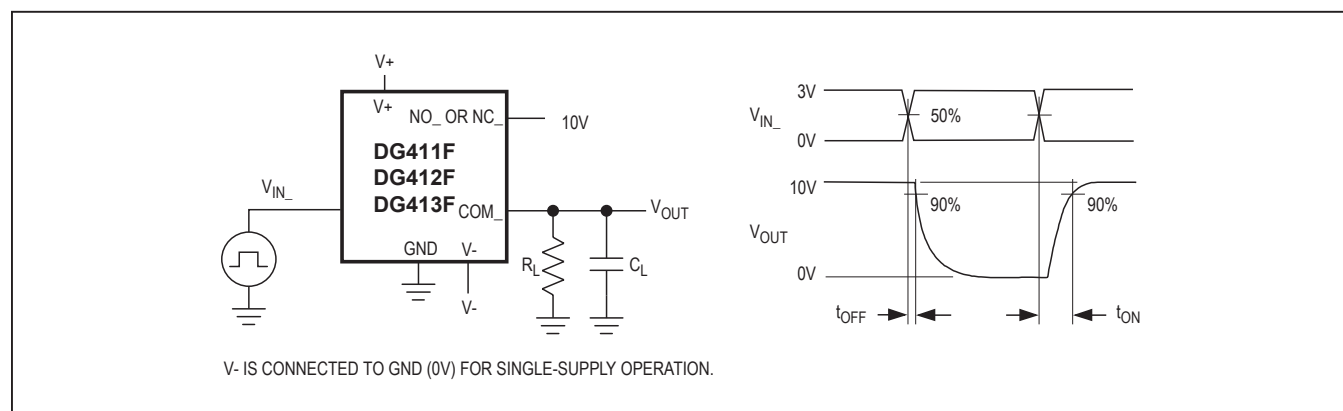
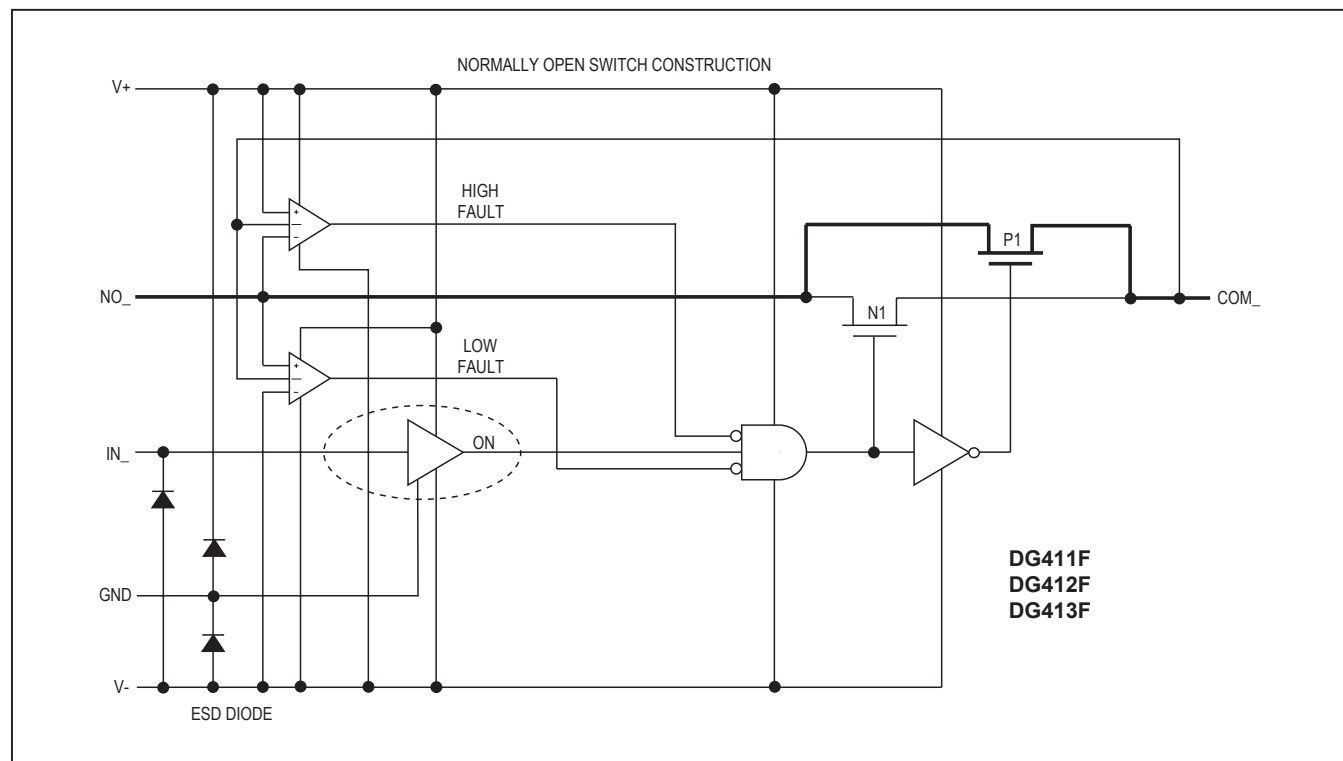
### Bipolar Supplies

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.

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



Test Circuits/Timing Diagrams (continued)

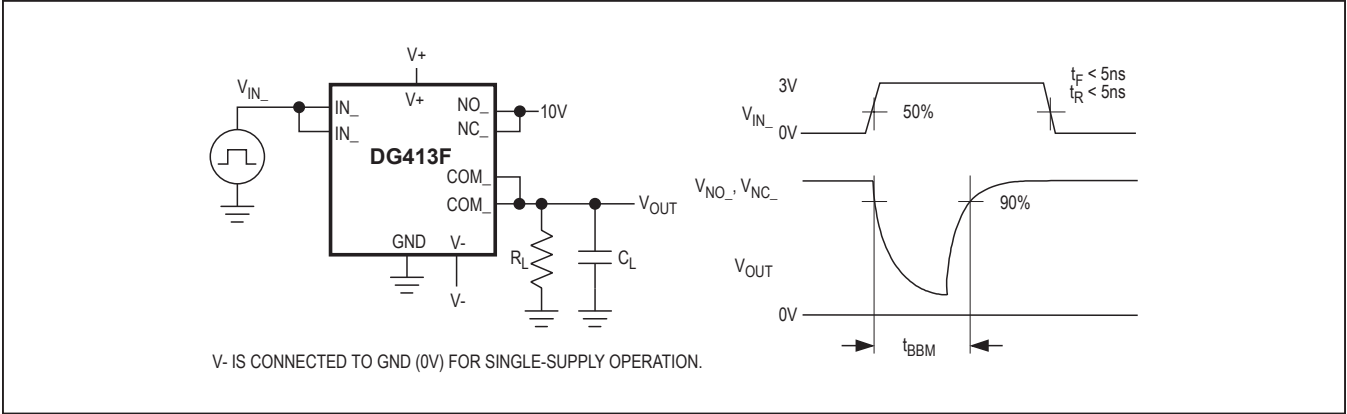


Figure 3. DG413F Break-Before-Make Interval

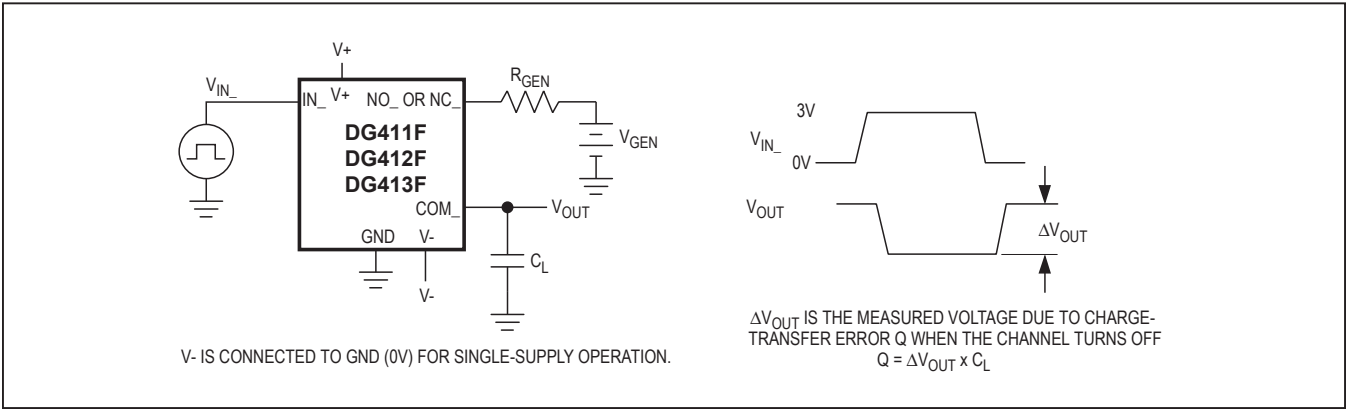


Figure 4. Charge Injection

## Test Circuits/Timing Diagrams (continued)

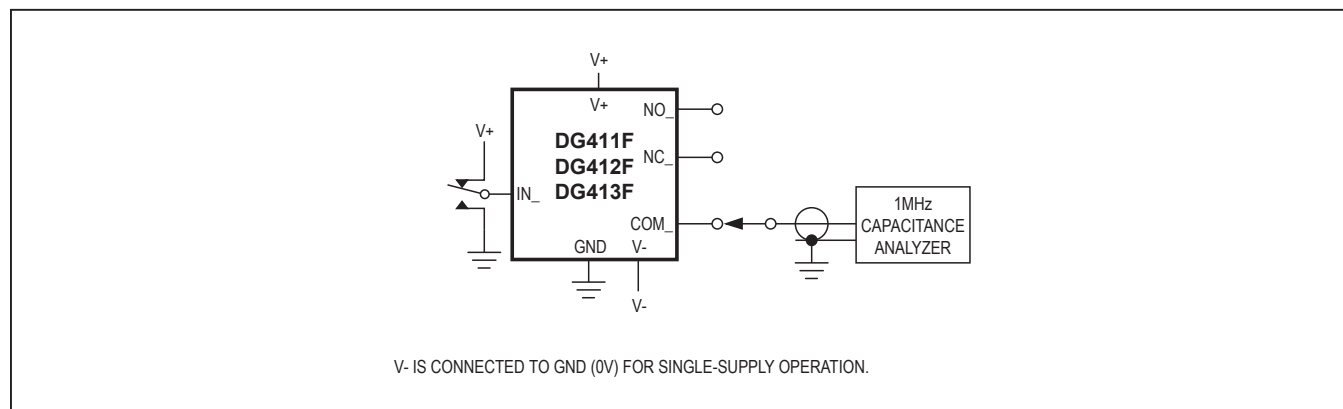


Figure 5. COM\_, NO\_, NC\_ Capacitance

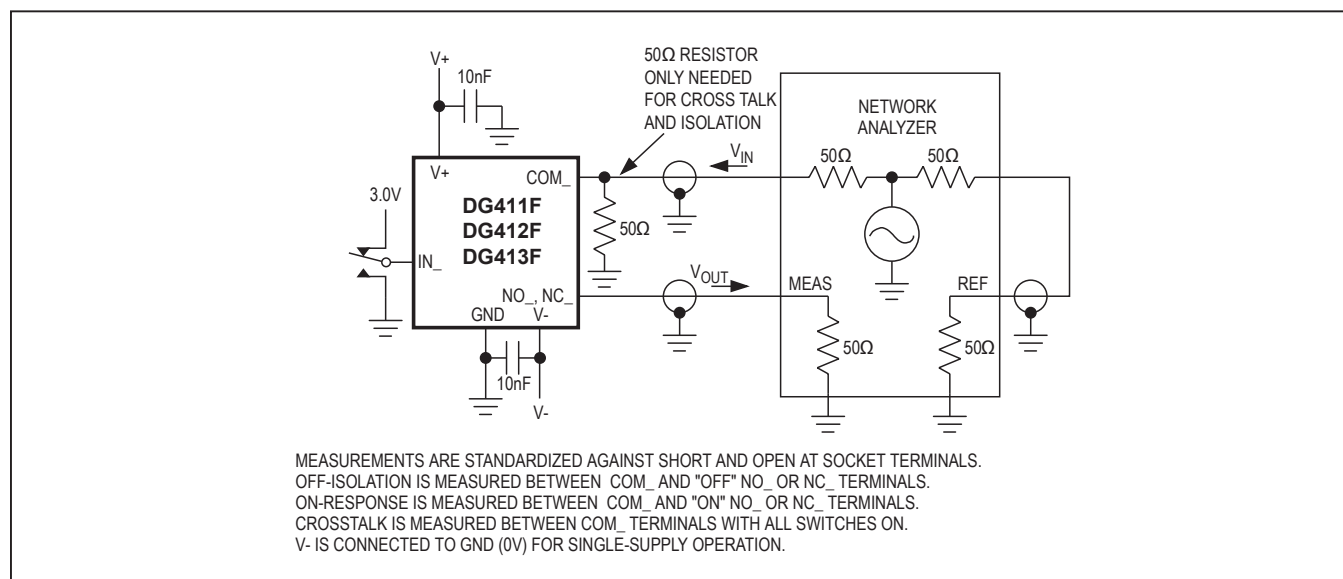


Figure 6. Frequency Response, Off-Isolation, and Crosstalk

DG411F/DG412F/  
DG413F

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

### Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
<b>DG411</b> FEUE	-40°C to +85°C	16 TSSOP
DG411FDY	-40°C to +85°C	16 SO
DG411FDJ	-40°C to +85°C	16 Plastic DIP
<b>DG412</b> FEUE	-40°C to +85°C	16 TSSOP
DG412FDY	-40°C to +85°C	16 SO
DG412FDJ	-40°C to +85°C	16 Plastic DIP
<b>DG413</b> FEUE	-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+

DG411F/DG412F/  
DG413F

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

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	4/02	Initial release	—
1	3/21	Updated <i>Electrical Characteristics</i> tables and <i>Package Information</i> table	2, 4, 11

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