

# NCS37013

## Self Test Ground Fault Circuit Interrupter (GFCI)

### Description

The NCS37013 is a fully UL943 compliant signal processor for GFCI applications with self test. The device integrates a flexible power supply (including a 12 V shunt and 2–5 V internal series regulators), differential fault, and grounded–neutral detection circuits. A proprietary self test algorithm is used to minimize the number of external components and improve performance. The device also includes a specialized DSP controller that offers best in class immunity to nuisance loads without the need for external analog filters. Self test is monitored every 17 minutes through an external current path and internally generated grounded neutral fault.

### Features

- 6.0 – 12 V Operation (120 – 480 V AC mains with the appropriate series impedance)
- –40 to 85°C
- Low Power Consumption: <15 mW @ 6 V
- 16 Pin QFN
- Full Self Test of both the Differential and Ground Neutral Current Transformers
- Self Syncing Internal Oscillator Adjusts to AC Mains Frequency to Guarantee Full Resolution on 50 and 60 Hz Distribution Systems
- Optimized Solenoid Deployment (coil is not energized near the AC mains zero crossings)
- Randomized Testing Sequence to Minimize Noise and Potential Interactions on the AC Mains
- >5 mA SCR Driver for use with High Igt SCR's for Improved Noise Immunity
- Superior Immunity to Nuisance Loads/Noise (up to 10 A) without Loss of Detection Capability or CT Saturation
- These Devices are Pb–Free, Halogen Free/BFR Free and are RoHS Compliant

### Typical Applications

- Load Panel GFCI Breakers
- GFCI Receptacles
- In–line GFCI Circuits (power cords)



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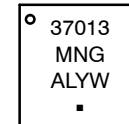
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QFN16  
MN SUFFIX  
CASE 485FQ

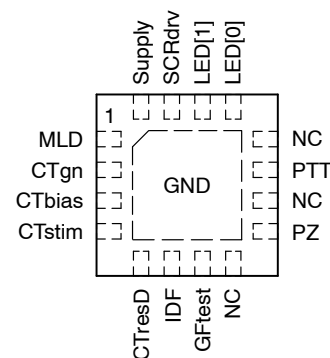
### MARKING DIAGRAM



37013MNG = Specific Device Code

- A = Assembly Location
- L = Wafer Lot
- Y = Year
- W = Work Week
- = Pb–Free Package

### PIN CONNECTIONS



(Top View)

### ORDERING INFORMATION

Device	Package	Shipping†
NCS37013MNTWG	QFN16 (Pb–Free)	3000 / Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.

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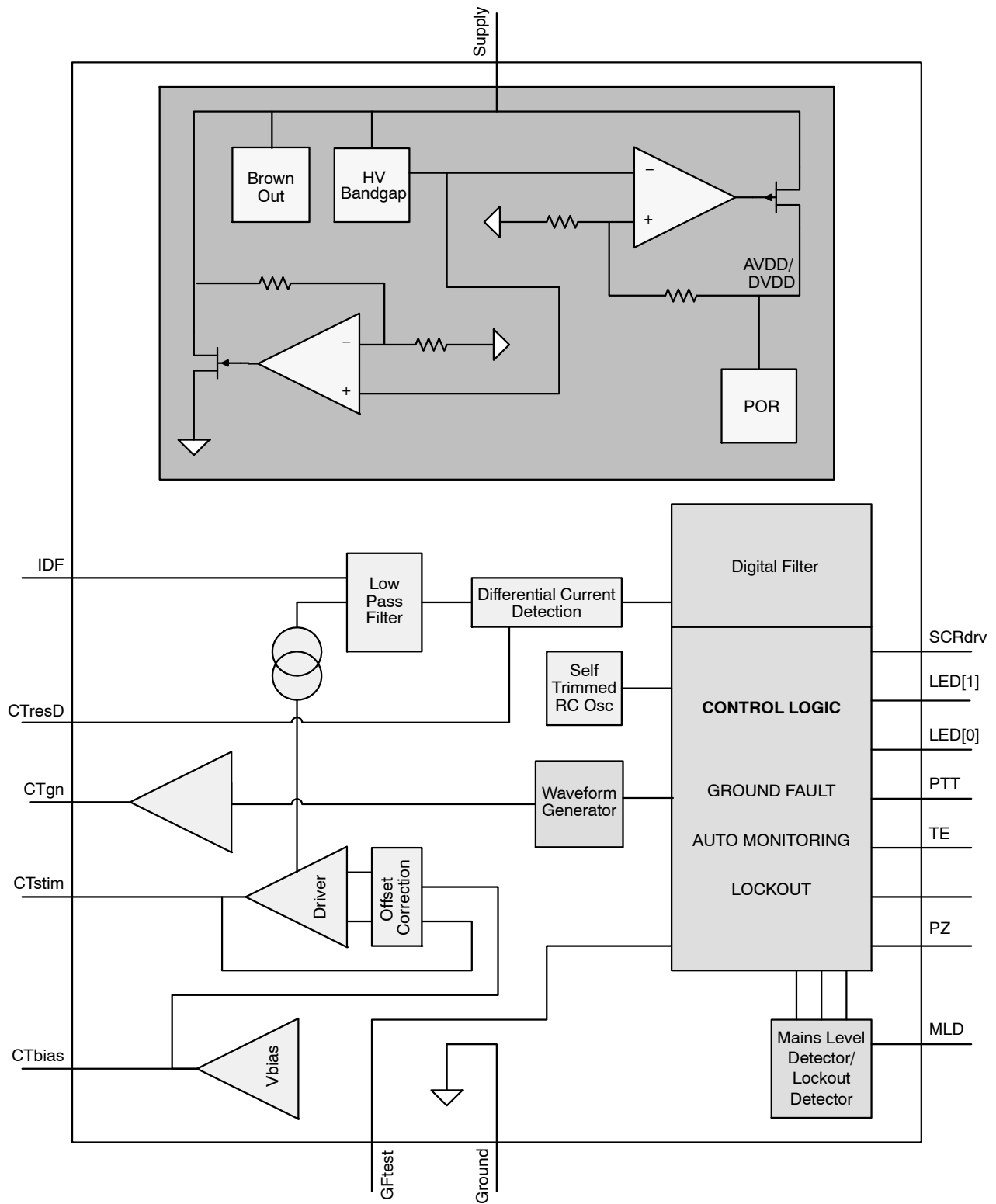


Figure 1. Simplified Block Diagram

**Table 1. QFN PIN DESCRIPTION**

Pin #	Name	Pad Description
0	Ground	QFN center slug
1	MLD	Mains Level Detect (Zero Cross)
2	CTgn	Determines IV converter gain for detection threshold / matched to CT turns ratio (Ground-Neutral)
3	CTbias	Direct connection to the CT
4	CTstim	Direct connection to the CT
5	CTresD	Determines IV converter gain for detection threshold / matched to CT turns ratio (Differential Current)
6	IDF	Front end noise filter capacitor
7	GFtest	Output to induce external differential current
8	NC	Not connected
9	PZ	Piezo output driver
10	NC	Tie to Ground or leave floating
11	PTT	Push to test input
12	NC	Tie to Ground or leave floating
13	LED[0]	LED[0] output driver
14	LED[1]	LED[1] output driver
15	SCRdrv	Used to trigger the solenoid at a fault detection
16	Supply	Power supply

**Table 2. ABSOLUTE MAXIMUM RATINGS**

Rating	Symbol	Value	Unit
Supply Voltage Range	V <sub>s</sub>	6.0 to 12 V	V
Input Voltage Range (Note 1)	V <sub>in</sub>	-0.3 to 6.0	V
Output Voltage Range	V <sub>out</sub>	-0.3 to 6.0 V or (V <sub>in</sub> + 0.3), whichever is lower	V
Maximum Junction Temperature	T <sub>J(max)</sub>	140	°C
Storage Temperature Range	T <sub>STG</sub>	-65 to 150	°C
ESD Capability, Human Body Model (Note 2)	ESD <sub>HBM</sub>	2	kV
ESD Capability, Machine Model (Note 2)	ESD <sub>MM</sub>	200	V
Lead Temperature Soldering Reflow (SMD Styles Only), Pb-Free Versions (Note 3)	T <sub>SLD</sub>	260	°C

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Refer to ELECTRICAL CHARACTERISTICS and APPLICATION INFORMATION for Safe Operating Area.
2. This device series incorporates ESD protection and is tested by the following methods:  
 ESD Human Body Model tested per AEC-Q100-002 (EIA/JESD22-A114)  
 ESD Machine Model tested per AEC-Q100-003 (EIA/JESD22-A115)  
 Latchup Current Maximum Rating: ≤ 150 mA per JEDEC standard: JESD78
3. For information, please refer to our Soldering and Mounting Techniques Reference Manual, SOLDERRM/D

**Table 3. THERMAL CHARACTERISTICS**

Rating	Symbol	Value	Unit
Thermal Characteristics, QFN16, 3x3.3 mm (Note 4) Thermal Resistance, Junction-to-Air (Note 5)	R <sub>θJA</sub>	64	°C/W

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

4. Refer to ELECTRICAL CHARACTERISTICS and APPLICATION INFORMATION for Safe Operating Area.
5. Values based on copper area of 645 mm<sup>2</sup> (or 1 in<sup>2</sup>) of 1 oz copper thickness and FR4 PCB substrate.

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**Table 4. OPERATING RANGES** (Note 6)

Parameter	Conditions	Min	Typ	Max	Units
Operating Temperature	Ambient	-40		85	C
Supply Shunt Regulator	Supply to GND	10	12	14	V
I <sub>DD</sub> in Typical Power State	Supply = 6 V		2		mA
SCR Trigger Current				8	mA
SCR Trigger Output Voltage	Supply < 6 V	4.5		5.5	V
CTstim Offset Voltage	Supply = 6 V	-9	0	9	mV
Fault Current Sensitivity	CTresD = 150 kΩ and Ndiff = 800	4.5	5	5.5	mA
Ground Fault Response Time	5 – 20 mA			150	ms
Ground Fault Response Time	20 – 40 mA			75	ms
Ground Fault Response Time	>40 mA			25	ms
Saturation Fault Response Time	>300 mA		1.4		ms
Differential CT Turns Ratio		200		1000	
Ground Neutral Stimulus Frequency	Tri-tone	3.1		3.4	KHz
Ground Neutral Stimulus Amplitude	Ishunt = 1 mA	3.6	3.85	4.1	Vpk-pk
Ground Neutral Fault Threshold	Total series impedance (Rn and Rg)	3		6	Ω
Ground Neutral CT Turns Ratio		40	80	140	
Internal Oscillator Frequency			2		MHz

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

6. Refer to ELECTRICAL CHARACTERISTICS and APPLICATION INFORMATION for Safe Operating Area.

APPLICATIONS INFORMATION

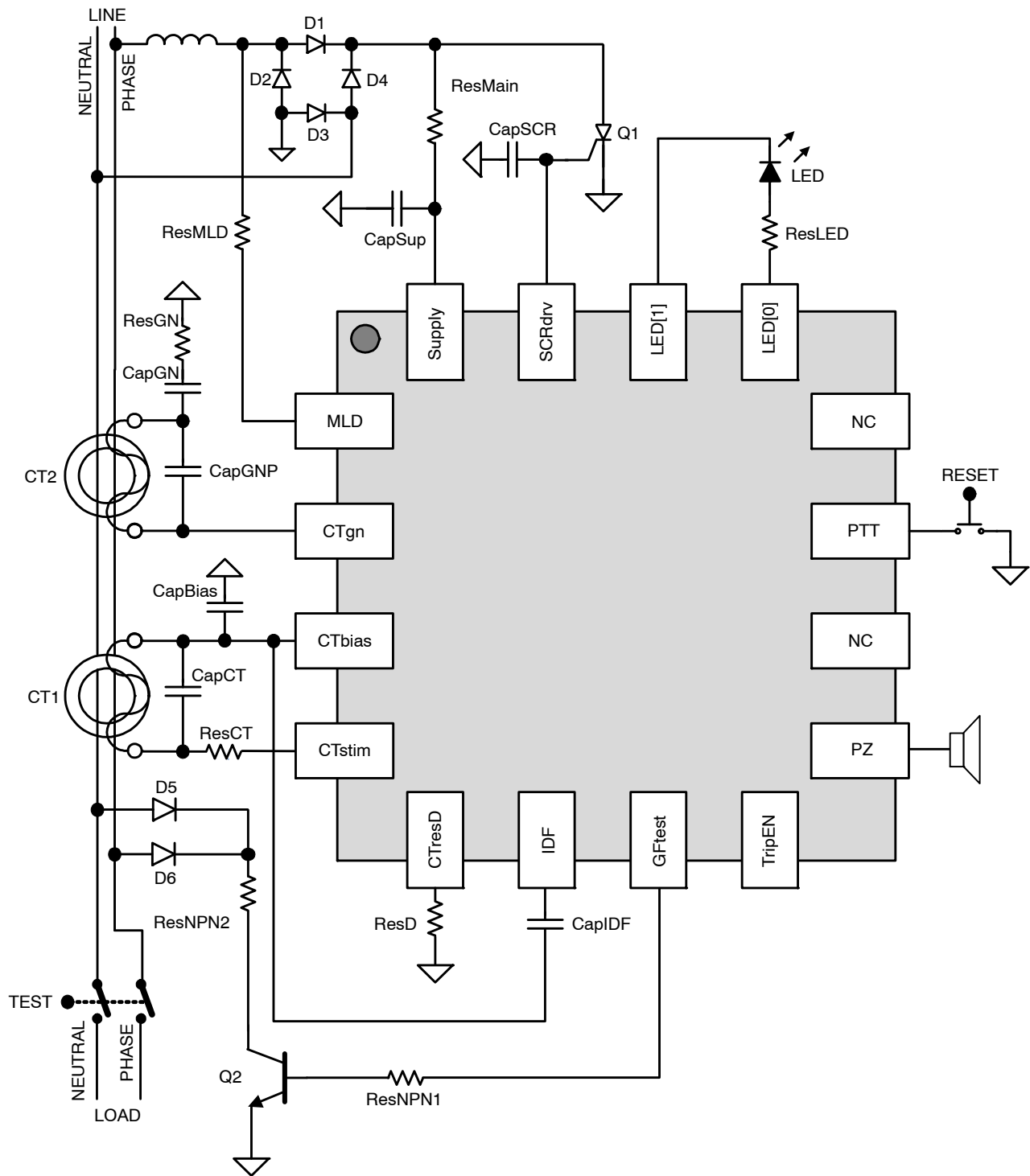


Figure 2. Self Test GFCI Receptacle

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## RECOMMENDED EXTERNAL COMPONENTS

Component Type	Instance	Value	Note
SCR	Q1	-	ON-MCR08
NPN	Q2	-	MMBT6517LT1-D
Diode	D1, D2, D3, D4, D5, D6	-	ON-1N4007
LED	LED	-	LED for self test failure
Capacitor	CapSup	1-4.7 $\mu$ F	Holding capacitor for a full wave rectified supply
Capacitor	CapGNP	10-1000 pF	Resonance capacitor for GN core
Capacitor	CapGN	0.1-2.2 $\mu$ F	AC coupling capacitor for GN core
Capacitor	CapIDF	220 nF	Sets the differential corner frequency at 1 kHz
Capacitor	CapBias	10 nF	Filtering component for CTbias voltage.
Capacitor	CapCT	1-10 nF	Filtering component for differential CT
Capacitor	CapSCR	1-10 nF	Filtering component.
Resistor	ResD	40-200 k $\Omega$	Set for differential trip level and turns ratio of CT1
Resistor	ResCT	0-100 $\Omega$	Filtering component that also sets differential
Resistor	ResGN	0-100 $\Omega$	
Resistor	ResMLD	200-800 k $\Omega$	Limiting resistor for the Mains Level Detector (MLD) input.
Resistor	ResMAIN	10-20 k $\Omega$	Limiting resistor that sets the allowable current
Resistor	ResNPN1	10 k $\Omega$	
Resistor	ResNPN2	15 k $\Omega$	Sets the external differential test current (8 mA)
Resistor	ResLED	1-5 k $\Omega$	Sets the brightness of the LEDs.
Current Transformer	CT1	-	Differential current transformer (N = 200-1000)
Current Transformer	CT2	-	GN current transformer (N = 40-140)

## LED AND SPEAKER FUNCTIONS

Device Function	Device State	Status Indicator Light	Speaker
Normal	No Power / Line Load Reversed	OFF	OFF
	Power Up	ON (Green)	OFF
		Blink once within 3 sec (Red)	
	Reset (Entered through PTT)	ON (Green)	ON (250 ms)
		Blink once within 3 sec (Red)	
Tripped	ON (Green)	OFF	
Abnormal	Self-Test Fails (Tripped)	Blink (Red)	OFF
	Self-Test Fails (Reset)	Blink (Red)	ON
	No Fault Removal on SCR	Blink (Red)	ON
	MLD Stuck (Tripped)	Blink (Red)	OFF
	MLD Stuck (Reset)	Blink (Red)	ON
	Tripped with Fault	Blink (Red)	OFF
	Illegal PTT (Reset)	Blink (Red)	ON

**Filtering**

The analog signal capture portion of the IC includes a single pole filter that can be set externally with CapIDF. The corner frequency is set with the following equation:

$$f_{idf} = \frac{1}{2\pi \cdot 1000 \cdot \text{CapIDF}}$$

For a 1 kHz corner frequency CapIDF should be set at 220 nF.

**Setting Differential Trip Threshold**

The ResD resistor sets the differential current trip threshold with the following equation:

$$I_{diff} = \frac{N_{diff}(R_{CT1} + \text{ResCT} + 2\pi f_{AC}L_{CT1})}{\text{ResD}(R_{CT1} + 2\pi f_{AC}L_{CT1})}$$

$N_{diff}$  = Turns ratio of differential CT

$R_{CT1}$  = DC winding resistance of differential CT

$f_{AC}$  = AC mains frequency

$L_{CT1}$  = Inductance of differential CT

**Setting Grounded–Neutral Trip Threshold**

The grounded–neutral trip threshold is set by the following equation:

$$R_{GN} = \frac{280}{N_{GN}}$$

$N_{GN}$  = Turns ratio of grounded–neutral CT

**Self Test**

Automatic self test will occur every 17 minutes. If a failure is observed it will be retested every minute until it passes. If it fails 8 successive tests then the GFCI will indicate that it has failed self test. See the LED and speaker functions table to see the different self test indicators. If TripEN is asserted high the GFCI unit will trip.

Differential ground fault test – tests the CT and the internal differential detection signal path by asserting the GFtest output high for 2 half cycles. The test will pass if a 6–8 mA differential current is enabled during these two half waves. Greater than 20 mA current during this test will cause a fault to be detected.

Ground neutral fault test – tests the connectivity of the GN CT and verifies the integrity of the stimulus waveform. If the CT is open or shorted the IC will detect and indicate or open the contacts.

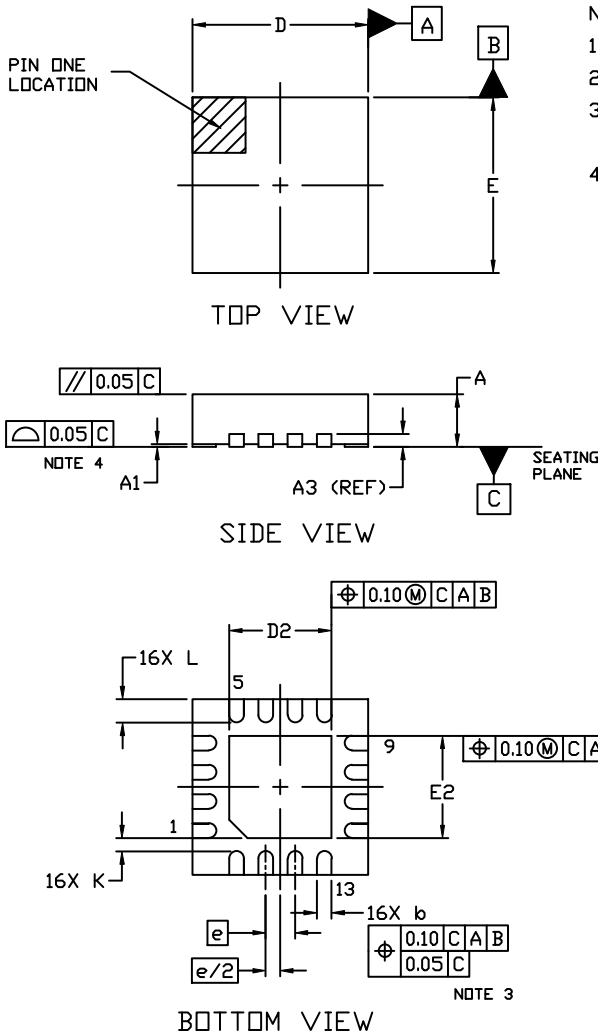
**PTT**

When the PTT input pin is de–asserted for greater than 80 ms a self test will be performed. If this test is successful the SCR will assert which will trip the GFCI unit. If the test is unsuccessful the LED[0] pin will flash indicating a failure.

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## PACKAGE DIMENSIONS

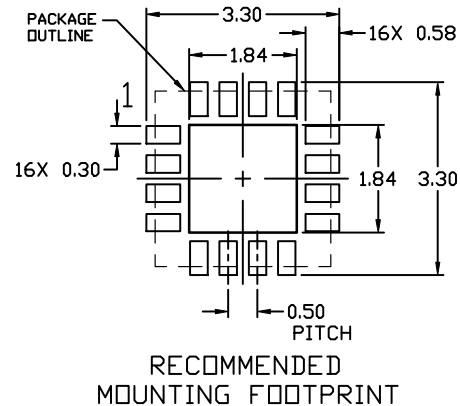
**QFN16 3x3, 0.5P**  
CASE 485FQ  
ISSUE A



**NOTES:**

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS
3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.25 AND 0.30 MM FROM THE TERMINAL TIP.
4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.

DIM	MILLIMETERS		
	MIN.	NOM.	MAX.
A	0.80	0.90	1.00
A1	---	---	0.05
A3	0.20 REF		
b	0.18	0.24	0.30
D	2.95	3.00	3.05
D2	1.70	1.75	1.80
E	2.95	3.00	3.05
E2	1.70	1.75	1.80
e	0.50 BSC		
K	0.18 TYP		
L	0.30	0.40	0.50



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