

NCS37012

Self Test Ground Fault Circuit Interrupter (GFCI)

Description

The NCS37012 is a fully UL943 compliant signal processor for GFCI applications with self test. The device integrates a flexible power supply (including both shunt and LDO regulators), differential fault, and grounded-neutral detection circuits. Proprietary impedance measurement and signal processing techniques are 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 V – 12 V Operation (120 – 480 V AC mains with the appropriate series impedance)
- –40 to 85°C
- Very Low Power Consumption: <15 mW @ 5 V
- 16 Pin QFN Package or 20 Pin TSSOP Package
- Single Current Transformer (CT) Detection of both Differential and Grounded–Neutral Faults
- Full Self Test and Trip Indicator Monitoring
- 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

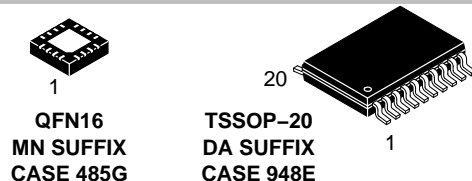
Typical Applications

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

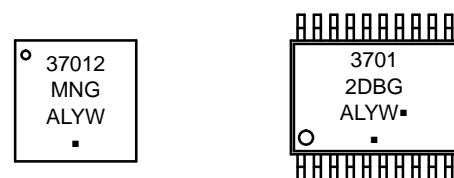


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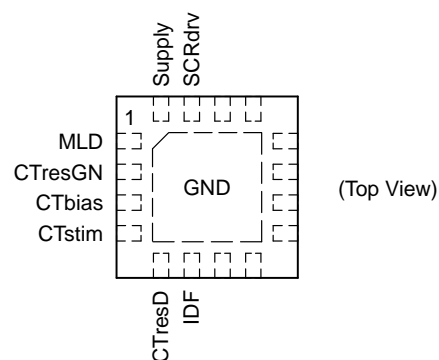
MARKING DIAGRAMS



XXXXX = Specific Device Code
 A = Assembly Location
 L = Wafer Lot
 Y = Year
 W = Work Week
 ▪ = Pb–Free Package

(Note: Microdot may be in either location)

PIN CONNECTIONS



ORDERING INFORMATION

| Device | Package | Shipping† |
|---------------|----------------------|--------------------|
| NCS37012MNTWG | QFN16 (Pb–Free) | 3000 / Tape & Reel |
| NCS37012DBRG | TSSOP20 (Pb–Free) | 2500 / 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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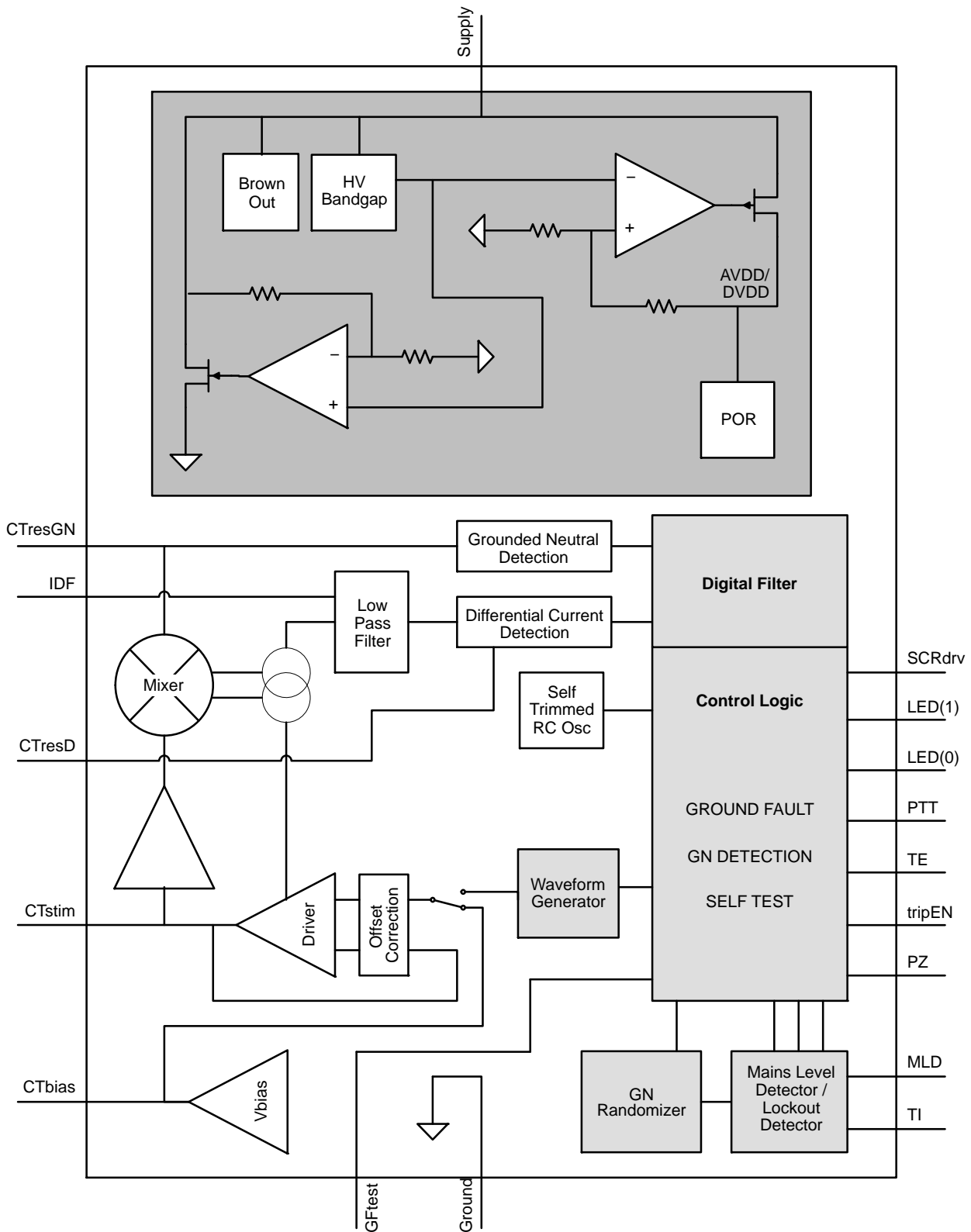


Figure 1. Simplified Block Diagram

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Table 1. PIN FUNCTION DESCRIPTION – QFN

| Pin # | Name | Pad Description |
|-------|---------|---|
| 0 | Ground | QFN center slug |
| 1 | MLD | Mains Level Detect (Zero Cross) |
| 2 | CTresGN | 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 | TripEN | (H) Trip / (L) No Trip on Self Test Failure |
| 9 | PZ | Piezo output driver |
| 10 | NC | Tie to Ground or leave floating |
| 11 | PTT | Push to test input |
| 12 | TI | Tip indicator input |
| 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. PIN FUNCTION DESCRIPTION – TSSOP

| Pin # | Name | Pad Description |
|-------|---------|---|
| 1 | CTstim | Differential and ground to neutral stimulus point for the current transformer |
| 2 | Ground | Ground connection for IC |
| 3 | CTresD | Determines IV converter gain for detection threshold / matched to CT turns ratio (Differential Current) |
| 4 | IDF | Determines corner frequency of the differential current path filter |
| 5 | GFtest | Output to induce external differential current |
| 6 | TripEN | (H) Trip / (L) No Trip on Self Test Failure |
| 7 | PZ | Piezo output driver |
| 8 | NC | Tie to Ground or leave floating |
| 9 | PTT | Push to test input |
| 10 | TI | Tip indicator input |
| 11 | Ground | Ground connection for IC |
| 12 | LED[0] | LED[0] output driver |
| 13 | LED[1] | LED[1] output driver |
| 14 | SCRdrv | Used to trigger the solenoid at a fault detection |
| 15 | DVDD | Internal digital 5 V regulated supply |
| 16 | AVDD | Internal analog 5 V regulated supply |
| 17 | Supply | 12 V shunt regulated power supply |
| 18 | MLD | Mains Level Detect (Zero Cross) and AM slope detect (for oscillator sync/trim and AM init) |
| 19 | CTresGN | Determines IV converter gain for detection threshold / matched to CT turns ratio (Ground-Neutral) |
| 20 | CTbias | External 2 V bias for the current transformer |

Table 3. ABSOLUTE MAXIMUM RATINGS

| Rating | Symbol | Value | Unit |
|---|---------------------|---|------|
| Supply Voltage Range | V _s | 6.0 to 12 V | V |
| Input Voltage Range (Note 1) | V _{in} | -0.3 to 6.0 | V |
| Output Voltage Range | V _{out} | -0.3 to 6.0 V or (V _{in} + 0.3), whichever is lower | V |
| Maximum Junction Temperature | T _{J(max)} | 140 | °C |
| Storage Temperature Range | T _{STG} | -65 to 150 | °C |
| ESD Capability, Human Body Model (Note 2) | ESD _{HBM} | 2 | kV |
| ESD Capability, Machine Model (Note 2) | ESD _{MM} | 200 | V |
| Lead Temperature Soldering Reflow (SMD Styles Only), Pb-Free Versions (Note 3) | T _{SLD} | 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 4. THERMAL CHARACTERISTICS

| Rating | Symbol | Value | Unit |
|--|--------------------------------------|------------|------|
| Thermal Characteristics, QFN16, 3x3.3 mm (Note 4) Thermal Resistance, Junction-to-Air (Note 5) Thermal Reference, Junction-to-Lead2 (Note 5) | R _{θJA} R _{ψJL} | TBD TBD | °C/W |
| Thermal Characteristics, TSSOP-20 (Note 4) Thermal Resistance, Junction-to-Air (Note 5) | R _{θJA} | TBD | °C/W |

4. Refer to ELECTRICAL CHARACTERISTICS and APPLICATION INFORMATION for Safe Operating Area.
5. Values based on copper area of 645 mm² (or 1 in²) of 1 oz copper thickness and FR4 PCB substrate.

Table 5. OPERATING RANGES (Note 6)

| Parameter | Conditions | Min | Typ | Max | Units |
|--------------------------------------|---|-----|-----|-----|-------|
| Operating Temperature | | -40 | | 85 | C |
| IDD in typical power state | | | 2.0 | | mA |
| Stimulus Generator Frequency | Tri-tone | 3.1 | | 3.4 | kHz |
| SCR Trigger Current | | | | 8.0 | mA |
| SCR Trigger output voltage | With 5 V supply | 4.5 | | 5.5 | V |
| Fault Current Sensitivity | Programmable with CTresD | 4.6 | 4.8 | 5.0 | 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 |
| CT Turns Ratio | | 200 | | 300 | |
| Ground – Neutral Detection Threshold | Total series impedance (R _n and R _g) | 3.0 | | 6.0 | Ω |
| Internal Oscillator Frequency | | | 2.0 | | MHz |
| CT Stimulus Current | Internally limited | | | 1.0 | mA |
| CT Driver Closed Loop BW | | | | 500 | kHz |

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.

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

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RECOMMENDED EXTERNAL COMPONENTS:

| Component Type | Instance | Value | Note |
|----------------|----------|-------------|--|
| SCR | Q1 | - | ON-MCR08 |
| Diode | Dx | - | ON-1N4007 |
| NPN | Q2 | - | MMBT6517LT1G |
| LED | Lx | - | LED pins drive opposite polarities |
| Capacitor | CapSUP | 3.3 μ F | For a full bridge rectifier |
| Capacitor | CapGN | 1-10 nF | Matched to current transformer |
| Capacitor | CapIDF | 220 nF | Sets the differential corner frequency at 1 kHz |
| Capacitor | CapBias | 10 nF | Filtering component for CTbias voltage |
| Capacitor | CapCT | 2.2 - 10 nF | Filtering and resonant capacitor for CT |
| Capacitor | CapSCR | - | Filtering component |
| Resistor | ResD | 40 - 80k | Matched to current transformer |
| Resistor | ResGN | 100 - 400k | Matched to current transformer |
| Resistor | ResMLD | 400 - 800k | Limiting resistor for the Mains Level Detector (MLD) input |
| Resistor | ResTI | 400 - 800k | Limiting resistor for the Trip Indicator (TI) input |
| Resistor | ResMAIN | 10k | For a full bridge rectifier |
| Resistor | ResGFTST | 15k | Sets the external differential test current (8 mA) |
| Resistor | ResLED | 1-5k | Sets the brightness of the LEDs |
| TVS | T1 | - | ~250-400V |

LED AND SPEAKER FUNCTIONS

| Device Function | Device State | LED[0] | LED[1] | Speaker |
|-----------------|-------------------------------|--------------------------|--------|-------------|
| Normal | No Power / Line Load Reversed | OFF | LOW | OFF |
| | Power Up | HIGH for 500 ms | LOW | OFF |
| | Reset (Entered through PTT) | HIGH for 500 ms then LOW | HIGH | ON (250 ms) |
| | Tripped | LOW | HIGH | OFF |
| Abnormal | Self-Test Fails (Tripped) | (Blink) HIGH | LOW | OFF |
| | Self-Test Fails (Reset) | (Blink) HIGH | LOW | ON |
| | No Trip on Fault | (Blink) HIGH | LOW | ON |

Filtering

The analog signal capture portion of the IC includes a single pole filter that can be set externally with Cidf. This provides an additional layer of protection against false tripping under steady state noise conditions. High frequency steady state noise is common with pumps, motors or other cyclic noise generators.

$Cidf = 220 \text{ nF} = 1 \text{ kHz low pass.}$

For additional filtering suggestions please contact ON Semiconductor.

Setting Trip Sensitivity

The CTresD resistor sets the threshold for the differential current fault levels. Increasing CTresD causes the fault

levels to trip at lower differential currents. CT efficiency at 60 Hz must be considered.

$CTresD = 400 * \#Turns$ – Subject to CT efficiency at 60 Hz

The CTresGN resistor sets the threshold for ground to neutral fault detection. The Rt parameter is the desired ground to neutral resistance trip level. Higher CTresGN values will cause the part to trip at higher ground to neutral impedances.

$CTresGN = \#Turns^2 \times Rt/2$ – Subject to CT efficiency from 3 kHz to 4 kHz

Setting Grounded – Neutral Response Time

C_{gn} is used to define the response time of the grounded-neutral detection circuit. The analog portion converts the impedance into a DC voltage and a high frequency (aliased) component. The capacitor is used to remove the high frequency component leaving just the DC representation of the impedance.

$$CT_{capGN} = 1.8E-4 / CT_{resGN}$$

Self Test

Automatic self test will occur every 17 minutes. If a failure is observed it will be retested every second 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 internal ground neutral stimulus and detection paths by enabling an internal 50k resistor between the CTstim and CTbias pins. If the resistor and capacitor on CTresGN are connected this will pass the GN self test.

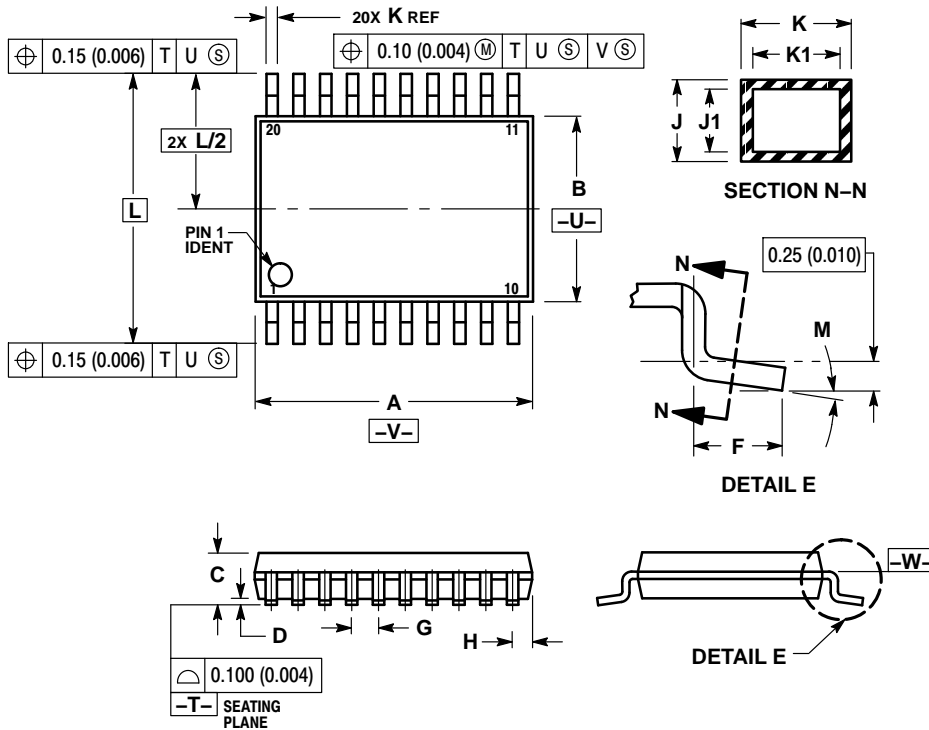
PTT

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 be fired 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

TSSOP-20
CASE 948E-02
ISSUE C

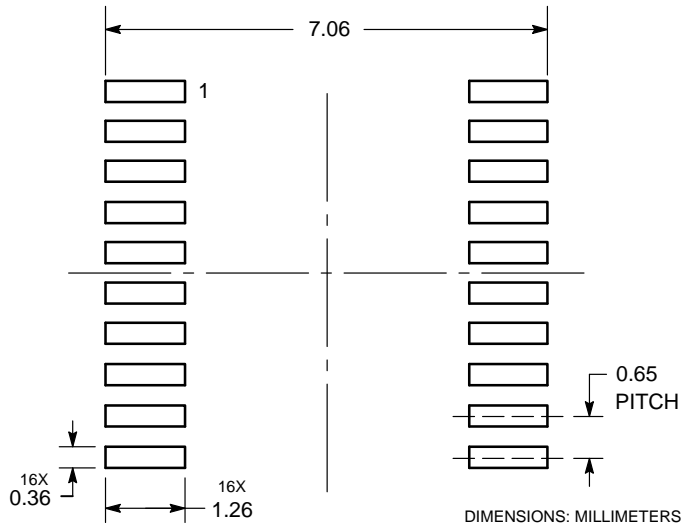


NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH OR GATE BURRS SHALL NOT EXCEED 0.15 (0.006) PER SIDE.
4. DIMENSION B DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25 (0.010) PER SIDE.
5. DIMENSION K DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.08 (0.003) TOTAL IN EXCESS OF THE K DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. TERMINAL NUMBERS ARE SHOWN FOR REFERENCE ONLY.
7. DIMENSION A AND B ARE TO BE DETERMINED AT DATUM PLANE -W-.

| DIM | MILLIMETERS | | INCHES | |
|-----|-------------|------|-----------|-------|
| | MIN | MAX | MIN | MAX |
| A | 6.40 | 6.60 | 0.252 | 0.260 |
| B | 4.30 | 4.50 | 0.169 | 0.177 |
| C | --- | 1.20 | --- | 0.047 |
| D | 0.05 | 0.15 | 0.002 | 0.006 |
| F | 0.50 | 0.75 | 0.020 | 0.030 |
| G | 0.65 BSC | | 0.026 BSC | |
| H | 0.27 | 0.37 | 0.011 | 0.015 |
| J | 0.09 | 0.20 | 0.004 | 0.008 |
| J1 | 0.09 | 0.16 | 0.004 | 0.006 |
| K | 0.19 | 0.30 | 0.007 | 0.012 |
| K1 | 0.19 | 0.25 | 0.007 | 0.010 |
| L | 6.40 BSC | | 0.252 BSC | |
| M | 0° | 8° | 0° | 8° |

SOLDERING FOOTPRINT

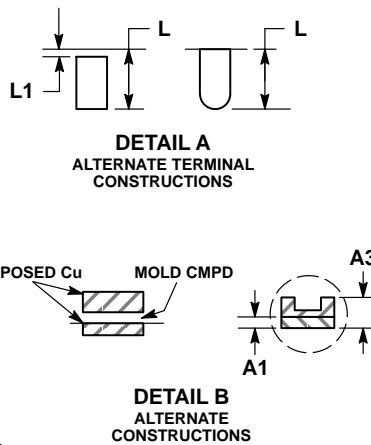
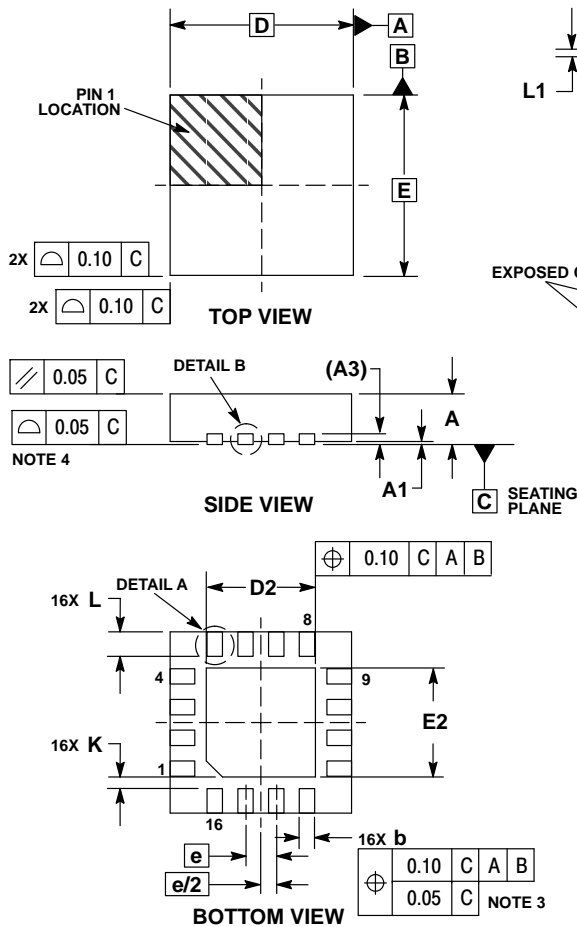


*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

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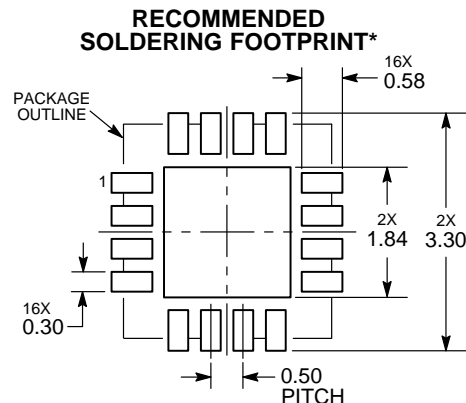
PACKAGE DIMENSIONS

QFN16 3x3, 0.5P
CASE 485G
ISSUE F



- 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 TERMINAL.
 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 | 0.00 | 0.03 | 0.05 |
| A3 | 0.20 REF | | |
| b | 0.18 | 0.24 | 0.30 |
| D | 3.00 BSC | | |
| D2 | 1.65 | 1.75 | 1.85 |
| E | 3.00 BSC | | |
| E2 | 1.65 | 1.75 | 1.85 |
| e | 0.50 BSC | | |
| K | 0.18 TYP | | |
| L | 0.30 | 0.40 | 0.50 |
| L1 | 0.00 | 0.08 | 0.15 |



DIMENSIONS: MILLIMETERS

*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

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