# 6-Channel EMI Filter with Integrated ESD Protection

# NUF6410MN

The NUF6410MN is a six−channel (C−R−C) Pi−style EMI filter array with integrated ESD protection. Its typical component values of R = 100 Ω and C = 7 pF deliver a cutoff frequency of 250 MHz and stop band attenuation greater than −20 dB from 800 MHz to 3.0 GHz.

This performance makes the part ideal for parallel interfaces with data rates up to 167 Mbps in applications where wireless interference must be minimized. The specified attenuation range is very effective in minimizing interference from 2G/3G, GPS, Bluetooth® and WLAN signals.

The NUF6010MU is available in the low−profile 12−lead 1.35 mm x 3.0 mm DFN12 surface mount package.

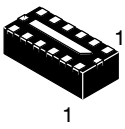
### Features/Benefits

- ±8.0 kV ESD Protection on each channel (IEC61000−4−2 Level 4, Contact Discharge)
- R/C Values of 100 Ω and 7 pF deliver Exceptional S21 Performance Characteristics of 250 MHz $f_{3dB}$ and −20 dB Stop Band Attenuation from 800 MHz to 3.0 GHz
- Integrated EMI/ESD System Solution in DFN Package Offers Exceptional Cost, System Reliability and Space Savings
- This is a Pb−Free Device

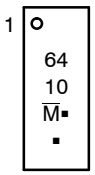
### Applications

- EMI Filtering for LCD and Camera Data Lines
- EMI Filtering and Protection for I/O Ports and Keypads

**MARKING DIAGRAM**




**DFN12**
**CASE 506AD**




6410 = Specific Device Code
M = Date and Assembly Location
▪ = Pb−Free Package
(Note: Microdot may be in either location)

**ORDERING INFORMATION**

| Device | Package | Shipping† |
|---|---|---|
| NUF6410MNT1G | DFN12 (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 Specifications Brochure, BRD8011/D.

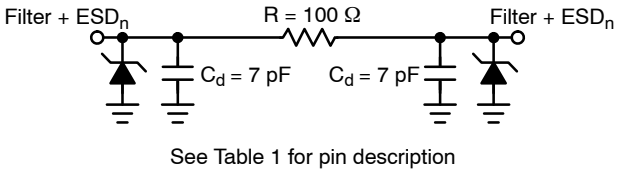



**Figure 1. Electrical Schematic**

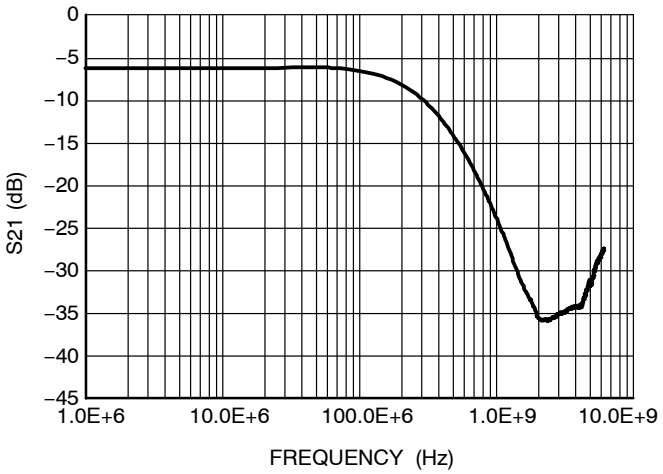



**Figure 2. Typical Insertion Loss Characteristic**

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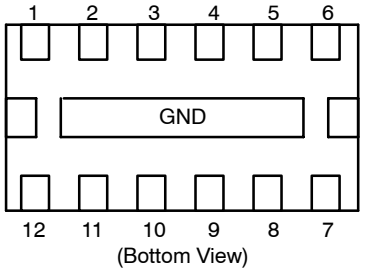



**Figure 3. Pin Diagram**

**Table 1. FUNCTIONAL PIN DESCRIPTION**

| Filter | Device Pins | Description |
|---|---|---|
| Filter 1 | 1 & 12 | Filter + ESD Channel 1 |
| Filter 2 | 2 & 11 | Filter + ESD Channel 2 |
| Filter 3 | 3 & 10 | Filter + ESD Channel 3 |
| Filter 4 | 4 & 9 | Filter + ESD Channel 4 |
| Filter 5 | 5 & 8 | Filter + ESD Channel 5 |
| Filter 6 | 6 & 7 | Filter + ESD Channel 6 |
| Ground Pad | GND | Ground |

**MAXIMUM RATINGS**

| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| ESD Discharge IEC61000−4−2 Contact Discharge | $V_{PP}$ | 8.0 | kV |
| DC Power per Resistor | $P_R$ | 100 | mW |
| DC Power per Package | $P_T$ | 600 | mW |
| Operating Temperature Range | $T_{OP}$ | −40 to 85 | °C |
| Storage Temperature Range | $T_{STG}$ | −55 to 150 | °C |
| Maximum Lead Temperature for Soldering Purposes (1.8 in from case for 10 seconds) | $T_L$ | 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.

**ELECTRICAL CHARACTERISTICS** ($T_J$ = 25°C unless otherwise noted)

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Maximum Reverse Working Voltage | $V_{RWM}$ | | | | 5.0 | V |
| Breakdown Voltage | $V_{BR}$ | $I_R$ = 1.0 mA | 6.0 | 7.0 | | V |
| Leakage Current | $I_R$ | $V_{RWM}$ = 3.3 V | | 10 | 100 | nA |
| Resistance | $R_A$ | $I_R$ = 20 mA | 85 | 100 | 115 | Ω |
| Diode Capacitance | $C_d$ | $V_R$ = 2.5 V, f = 1.0 MHz | | 7.0 | 9.0 | pF |
| Line Capacitance | $C_L$ | $V_R$ = 2.5 V, f = 1.0 MHz | | 14 | 18 | pF |
| 3 dB Cut−Off Frequency (Note 1) | $f_{3dB}$ | Above this frequency, appreciable attenuation occurs | | 250 | | MHz |
| 6 dB Cut−Off Frequency (Note 1) | $f_{6dB}$ | Above this frequency, appreciable attenuation occurs | | 400 | | MHz |

1. 50 Ω source and 50 Ω load termination.

## TYPICAL PERFORMANCE CURVES ($T_A$= 25°C unless otherwise specified)

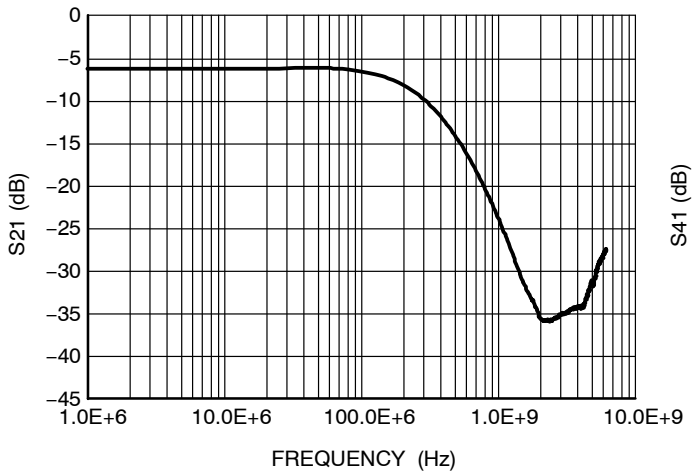



**Figure 4. Typical Insertion Loss Characteristic**

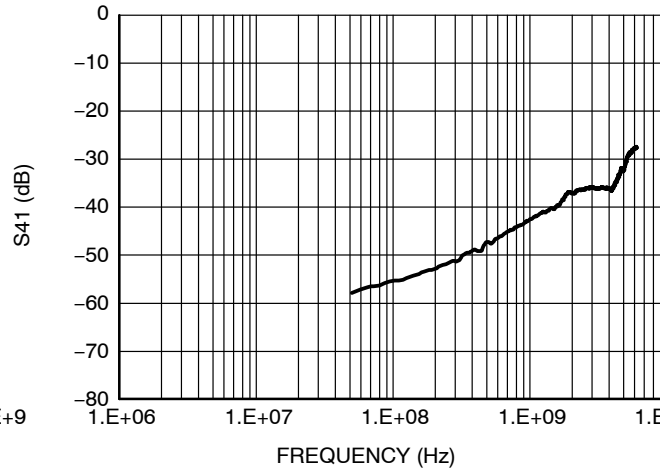



**Figure 5. Typical Analog Crosstalk**

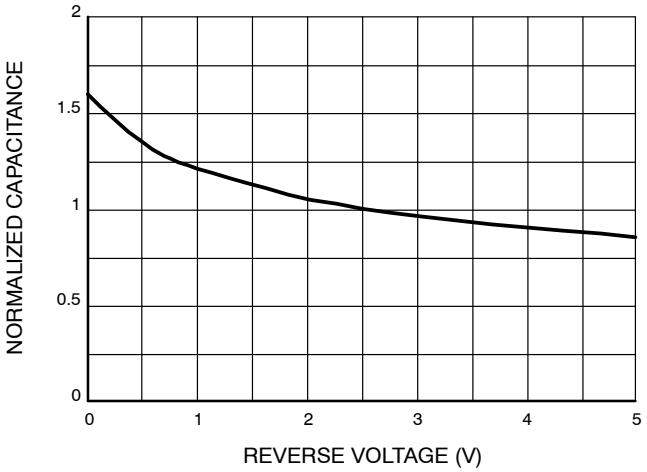



**Figure 6. Typical Capacitance vs. Reverse Biased Voltage (Normalized Capacitance, Cd @ 2.5 V)**

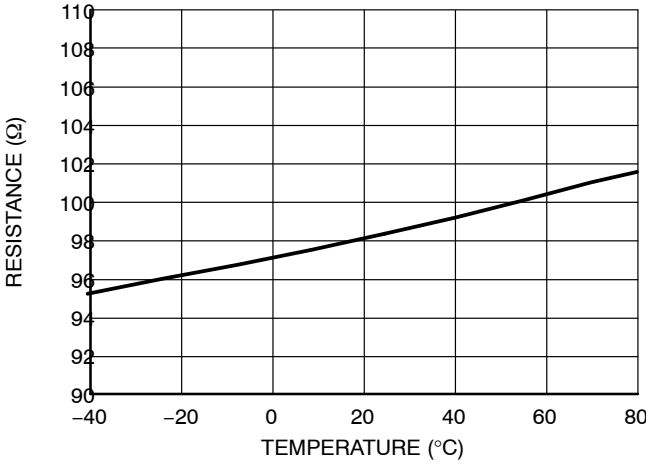



**Figure 7. Typical Resistance over Temperature**

### Theory of Operation

The NUF6410MN combines ESD protection and EMI filtering conveniently into a small package for today's size constrained applications. The capacitance inherent to a typical protection diode is utilized to provide the capacitance value necessary to create the desired frequency response based upon the series resistance in the filter. By combining this functionality into one device, a large number of discrete components are integrated into one small package saving valuable board space and reducing BOM count and cost in the application.

### Application Example

The accepted practice for specifying bandwidth in a filter is to use the 3 dB cutoff frequency. Utilizing points such as the 6 dB or 9 dB cutoff frequencies results in signal degradation in an application. This can be illustrated in an application example. A typical application would include EMI filtering of data lines in a camera or display interface. In such an example it is important to first understand the signal and its spectral content. By understanding these things, an appropriate filter can be selected for the desired application. A typical data signal is pattern of 1's and 0's transmitted over a line in a form similar to a square wave. The maximum frequency of such a signal would be the pattern 1-0-1-0 such that for a signal with a data rate of 100 Mbps, the maximum frequency component would be 50 MHz. The next item to consider is the spectral content of the signal, which can be understood with the Fourier series approximation of a square wave, shown below in Equations 1 and 2 in the Fourier series approximation.

From this it can be seen that a square wave consists of odd order harmonics and to fully construct a square wave n must go to infinity. However, to retain an acceptable portion of the waveform, the first two terms are generally sufficient. These two terms contain about 85% of the signal amplitude and allow a reasonable square wave to be reconstructed. Therefore, to reasonably pass a square wave of frequency *x* the minimum filter bandwidth necessary is *3x*. All **onsemi** EMI filters are rated according to this principle. Attempting to violate this principle will result in significant rounding of the waveform and cause problems in transmitting the correct data. For example, take the filter with the response shown in Figure 8 and apply three different data waveforms. To calculate these three different frequencies, the 3 dB, 6 dB, and 9 dB bandwidths will be used.

**Equation 1:**

$$x(t) = \frac{1}{2} + \frac{2}{\pi}\sum_{n=1}^{a}\left[\frac{1}{2n-1}\sin((2n-1)\omega_0 t)\right] \quad \text{(eq. 1)}$$

**Equation 2 (simplified form of Equation 1):**

$$x(t) = \frac{1}{2} + \frac{2}{\pi}\left[\frac{\sin(\omega_0 t)}{1} + \frac{\sin(3\omega_0 t)}{3} + \frac{\sin(5\omega_0 t)}{5} + \ldots\right] \text{(eq. 2)}$$

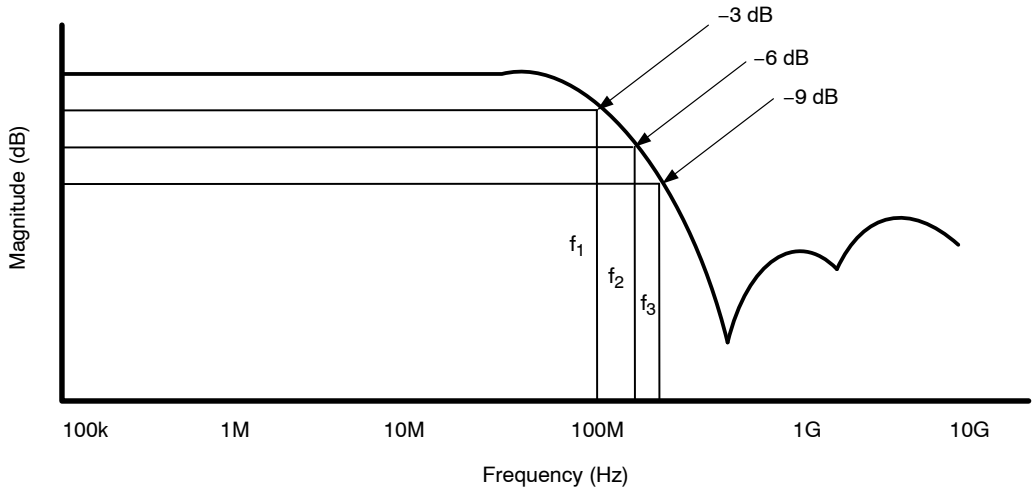



**Figure 8. Filter Bandwidth**

From the above paragraphs it is shown that the maximum supported frequency of a waveform that can be passed through the filter can be found by dividing the bandwidth by a factor of three (to obtain the corresponding data rate multiply the result by two). The following table gives the bandwidth values and the corresponding maximum supported frequencies and the third harmonic frequencies.

**Table 2. Frequency Chart**

| Bandwidth | Maximum Supported Frequency | Third Harmonic Frequency |
|---|---|---|
| 3 dB – 100 MHz | 33.33 MHz ($f_1$) | 100 MHz |
| 6 dB – 200 MHz | 66.67 MHz ($f_2$) | 200 MHz |
| 9 dB – 300 MHz | 100 MHz ($f_3$) | 300 MHz |

Considering that 85% of the amplitude of the square is in the first two terms of the Fourier series approximation most of the signal content is at the fundamental (maximum supported) frequency and the third harmonic frequency. If a signal with a frequency of 33.33 MHz is input to this filter, the first two terms are sufficiently passed such that the signal is only mildly affected, as is shown in Figure 9a. If a signal with a frequency of 66.67 MHz is input to this same filter, the third harmonic term is significantly attenuated. This serves to round the signal edges and skew the waveform, as is shown in Figure 9b. In the case that a 100 MHz signal is input to this filter, the third harmonic term is attenuated even further and results in even more rounding of the signal edges as is shown in Figure 9c. The result is the degradation of the data being transmitted making the digital data (1's and 0's) more difficult to discern. This does not include effects of other components such as interconnect and other path losses which could further serve to degrade the signal integrity. While some filter products may specify the 6 dB or 9 dB bandwidths, actually using these to calculate supported frequencies (and corresponding data rates) results in significant signal degradation. *To ensure the best signal integrity possible, it is best to use the 3 dB bandwidth to calculate the achievable data rate.*

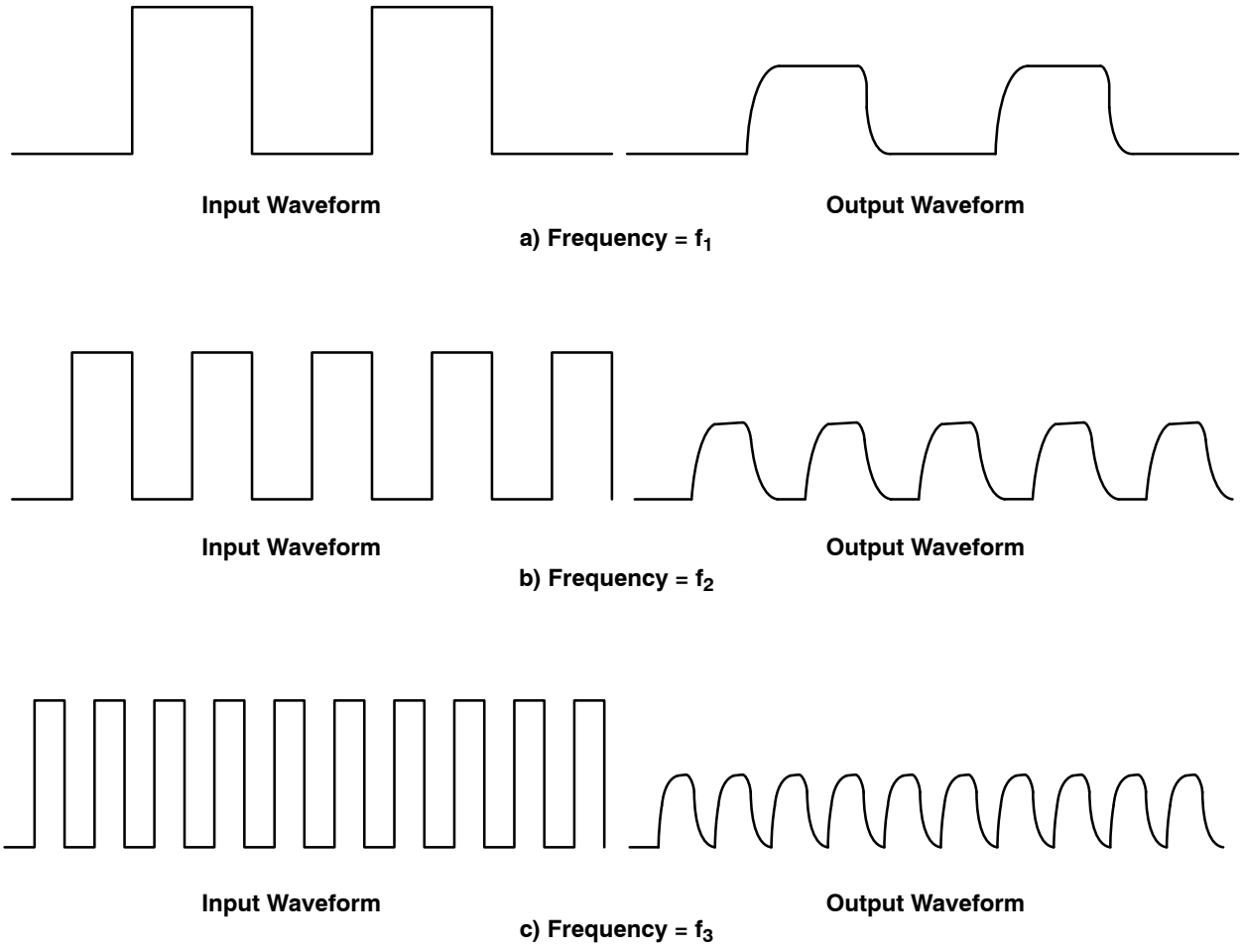
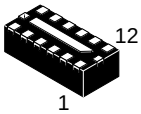



**Figure 9. Input and Output Waveforms of Filter**

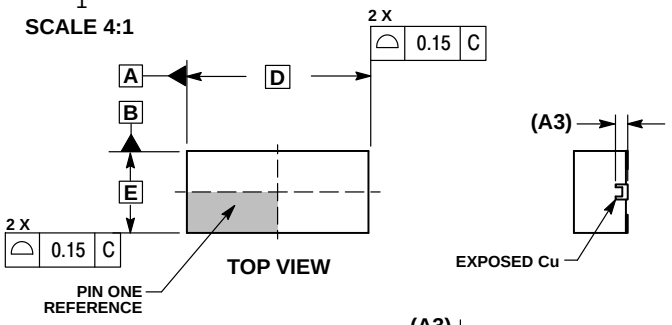
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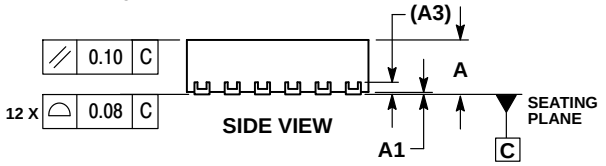
**DFN12 3.0x1.35, 0.5P**
CASE 506AD
ISSUE J

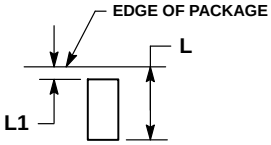
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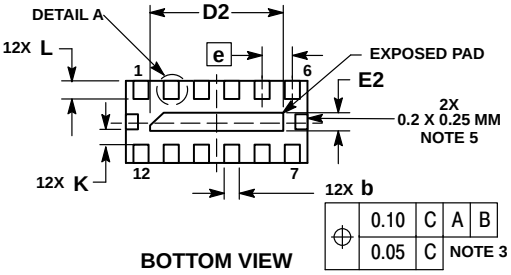

SCALE 4:1



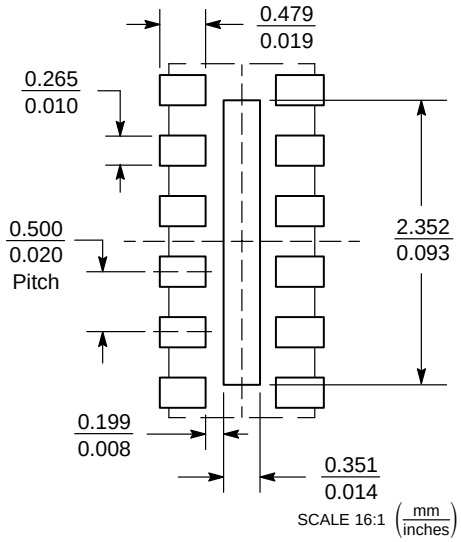




DETAIL A
OPTIONAL
CONSTRUCTION




BOTTOM VIEW

**SOLDERING FOOTPRINT***



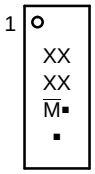

SCALE 16:1 (mm / inches)

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

NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETER.
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.
5. EXPOSED PADS CONNECTED TO DIE FLAG. USED AS TEST CONTACTS.

| | MILLIMETERS | |
|---|---|---|
| DIM | MIN | MAX |
| A | 0.80 | 1.00 |
| A1 | 0.00 | 0.05 |
| A3 | 0.20 REF | |
| b | 0.18 | 0.30 |
| D | 3.00 BSC | |
| D2 | 2.10 | 2.30 |
| E | 1.35 BSC | |
| E2 | 0.20 | 0.40 |
| e | 0.50 BSC | |
| K | 0.20 | −−− |
| L | 0.20 | 0.40 |
| L1 | 0.00 | 0.15 |

**GENERIC MARKING DIAGRAM***




XXXX = Specific Device Code
M = Month Code
▪ = Pb−Free Package

(Note: Microdot may be in either location)

*This information is generic. Please refer to device data sheet for actual part marking.
Pb−Free indicator, “G” or microdot “ ▪”, may or may not be present.

STYLE 1:
PIN 1. ANODE 1
2. ANODE 2
3. ANODE 3
4. ANODE 4
5. ANODE 5
6. ANODE 6
7. ANODE 7
8. ANODE 8
9. ANODE 9
10. ANODE 10
11. ANODE 11
12. ANODE 12

| | | | |
|---|---|---|---|
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| **DESCRIPTION:** | **DFN12 3.0x1.35, 0.5 MM PITCH** | | **PAGE 1 OF 1** |

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