



# VFC32

# Voltage-to-Frequency and Frequency-to-Voltage CONVERTER

# **FEATURES**

- OPERATION UP TO 500kHz
- EXCELLENT LINEARITY ±0.01% max at 10kHz FS ±0.05% max at 100kHz FS
- V/F OR F/V CONVERSION
- MONOTONIC
- VOLTAGE OR CURRENT INPUT

# **APPLICATIONS**

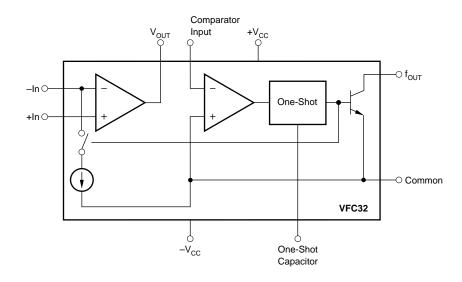
- INTEGRATING A/D CONVERTER
- SERIAL FREQUENCY OUTPUT
- ISOLATED DATA TRANSMISSION
- FM ANALOG SIGNAL MOD/DEMOD
- MOTOR SPEED CONTROL
- TACHOMETER

# DESCRIPTION

The VFC32 voltage-to-frequency converter provides an output frequency accurately proportional to its input voltage. The digital open-collector frequency output is compatible with all common logic families. Its integrating input characteristics give the VFC32 excellent noise immunity and low nonlinearity.

Full-scale output frequency is determined by an external capacitor and resistor and can be scaled over a wide range. The VFC32 can also be configured as a frequency-to-voltage converter.

The VFC32 is available in 14-pin plastic DIP, SO-14 surface-mount, and metal TO-100 packages. Commercial, industrial, and military temperature range models are available.



International Airport Industrial Park • Mailing Address: PO Box 11400 • Tucson, AZ 85734 • Street Address: 6730 S. Tucson Blvd. • Tucson, AZ 85706

Tel: (602) 746-1111 • Twx: 910-952-1111 • Cable: BBRCORP • Telex: 066-6491 • FAX: (602) 889-1510 • Immediate Product Info: (800) 548-6132

# **SPECIFICATIONS**

At  $T_A = +25$ °C and  $V_{CC} = \pm 15$ V, unless otherwise noted.

|  |   | V                | FC32KP, K             | Ü                     |            | VFC32BM | I            |            | VFC32SM |              |                         |
|--|---|------------------|-----------------------|-----------------------|------------|---------|--------------|------------|---------|--------------|-------------------------|
| PARAMETER  | CONDITIONS  | MIN              | TYP                   | MAX                   | MIN        | TYP     | MAX          | MIN        | TYP     | MAX          | UNITS                   |
| INPUT (V/F CONVERTER)                            | $F_{OLIT} = V_{IN}/7.5 R_1 C_1$                             |                  |                       |                       |            |         |              |            |         |              |                         |
| Voltage Range <sup>(1)</sup>                     | I   |                  |                       |                       |            |         |              |            |         |              |                         |
| Positive Input                                   |   | >0               |                       | +0.25mA               | *          |         | *            | *          |         | *            | V                       |
|  |   |                  |                       | x R <sub>1</sub>      |            |         |              |            |         |              |                         |
| Negative Input                                   |   | >0               |                       | -10                   | *          |         | *            | *          |         | *            | V                       |
| Current Range <sup>(1)</sup>                     |   | >0               |                       | +0.25                 | *          |         | *            | *          |         | *            | mA                      |
| Bias Current                                     |   |                  |                       |                       |            |         |              |            |         |              | l .                     |
| Inverting Input                                  |   |                  | 20                    | 100                   |            | *       | *            |            | *       | *            | nA                      |
| Noninverting Input Offset Voltage <sup>(2)</sup> |   |                  | 100                   | 250<br>4              |            | *<br>*  | *            |            | *       | *            | nA                      |
| Differential Impedance                           |   | 300    10        | 650    10             | 4                     | *          | *       | ক            | *          | *       | *            | mV<br>kΩ    pF          |
| Common-mode                                      |   | 300    10        | 030    10             |                       | ~          | ~       |              | ~          | ~       |              | K22    Pi               |
| Impedance  |   | 300    3         | 500    3              |                       | *          | *       |              | *          | *       |              | MΩ    pF                |
| INPUT (F/V CONVERTER)                            | V _ 75 B C E  | 333    3         | ****                  |                       |            |         |              | <u> </u>   | -       |              |                         |
| Impedance  | $V_{OUT} = 7.5 R_1 C_1 F_{IN}$                              | 50    10         | 150    10             |                       | *          | *       |              | *          | *       |              | kΩ    pF                |
| Logic "1"  |   | 30    10         | +1.0                  |                       | *          | ~       | *            | *          | ~       | *            | V V                     |
| Logic "0"  |   |                  | -0.05                 |                       | *          |         | *            | *          |         | *            | ľ                       |
| Pulse-width Range                                |   | 0.1              | 0.00                  | 150k/F <sub>MAX</sub> | *          |         | *            | *          |         | *            | μs                      |
| ACCURACY   |   | ***              |                       | MAX.                  | -          |         | · ·          | <u> </u>   |         | -            | F                       |
| Linearity Error <sup>(3)</sup>                   | 0.01Hz ≤ Oper   |                  |                       |                       |            |         |              |            |         |              |                         |
| Emodity Emoi                                     | Freq ≤ 10kHz  |                  | ±0.005                | ±0.010(4)             |            | *       | *            |            | *       | *            | % of FSR <sup>(5)</sup> |
|  | 0.1Hz ≤ Oper  |                  |                       |                       |            | •       |              |            | '       | .            |                         |
|  | Freq ≤ 100kHz   |                  | ±0.025                | ±0.05                 |            | *       | *            |            | *       | *            | % of FSR                |
|  | 0.5Hz ≤ Oper  |                  |                       |                       |            |         |              |            |         |              |                         |
|  | Freq ≤ 500kHz   |                  | ±0.05                 |                       |            | *       |              |            | *       |              | % of FSR                |
| Offset Error Input                               |   |                  |                       |                       |            |         |              |            |         |              |                         |
| Offset Votlage(2)                                |   |                  | 1                     | 4                     |            | *       | *            |            | *       | *            | mV                      |
| Offset Drift <sup>(6)</sup>                      |   |                  | ±3                    |                       |            | *       |              |            | *       |              | ppm of FSR/°C           |
| Gain Error <sup>(2)</sup>                        |   |                  | 5                     |                       |            | *       |              |            | *       |              | % of FSR                |
| Gain Drift <sup>(6)</sup>                        | f = 10kHz   |                  | ±75                   |                       |            | ±50     | ±100         |            | ±70     | ±150         | ppm/°C                  |
| Full Scale Drift                                 | f = 10kHz   |                  | ±75                   |                       |            | ±50     | ±100         |            | ±70     | ±150         | ppm of FSR/°C           |
| (offset drift and                                |   |                  |                       |                       |            |         |              |            |         |              |                         |
| gain drift) <sup>(6, 7)</sup> Power Supply       | f = DC +V = 12VDC   |                  |                       |                       |            |         |              |            |         |              |                         |
| Sensitivity                                      | $f = DC$ , $\pm V_{CC} = 12VDC$<br>to $18VDC$               |                  |                       | ±0.015                |            |         | *            |            |         | *            | % of FSR/%              |
| OUTPUT (V/F CONVERTE                             |   |                  |                       | ±0.010                |            |         | 4"           | -          |         |              | 70 01 1 010 70          |
|  |   |                  |                       |                       |            |         |              |            |         |              |                         |
| Voltage, Logic "0"                               | I <sub>SINK</sub> = 8mA                                     | 0                | 0.2                   | 0.4                   | *          | *       | *            | *          | *       | *            | V                       |
| Leakage Current,                                 |   |                  |                       |                       |            |         |              |            |         |              | l .                     |
| Logic "1"  | V <sub>o</sub> = 15V  |                  | 0.01                  | 1.0                   |            | *       | *            |            | *       | *            | μΑ                      |
| Voltage, Logic "1"                               | External Pull-up Resistor<br>Required (see Figure 4)        |                  |                       | .,                    |            |         |              |            |         |              | V                       |
| Pulse Width                                      | For Best Linearity  |                  | 0.25/F <sub>MAX</sub> | V <sub>PU</sub>       |            | *       | *            |            | *       | *            |                         |
| Fall Time  | $I_{OUT} = 5\text{mA}, C_{LOAD} = 500\text{pF}$             |                  | 0.23/1 <sub>MAX</sub> | 400                   |            | ~       | *            |            | ~       | *            | s<br>ns                 |
|  |   |                  |                       | 400                   |            |         | 4            |            |         |              | 110                     |
| OUTPUT (F/V CONVERTE                             |   |                  |                       |                       |            |         |              |            |         |              |                         |
| Voltage  | I <sub>o</sub> ≤ 7mA  | 0 to +10         |                       |                       | *          |         |              | *          |         |              | V                       |
| Current  | V <sub>o</sub> ≤ 7VDC                                       | +10              |                       |                       | *          |         |              | *          |         |              | mA                      |
| Impedance  | Closed Loop   |                  |                       | 1                     |            |         | *            |            |         | *            | Ω                       |
| Capacitive Load                                  | Without Oscillation   |                  |                       | 100                   |            |         | *            |            |         | *            | pF                      |
| DYNAMIC RESPONSE                                 |   |                  |                       |                       |            |         |              | <b>l</b> . |         |              |                         |
| Full Scale Frequency                             |   |                  |                       | 500(8)                | *          |         |              | *          |         |              | kHz                     |
| Dynamic Range                                    | (\//E) to Coopidical Line                                   | 6                |                       |                       | *          |         |              | *          |         |              | decades                 |
| Settling Time                                    | (V/F) to Specified Linearity<br>for a Full Scale Input Step |                  | (9)                   |                       |            | *       |              |            | *       |              |                         |
| Overload Recovery                                | < 50% Overload  |                  | (9)                   |                       |            | *       |              |            | *       |              |                         |
|  | V 0070 Overload   | -                |                       |                       |            | •••     | -            | -          | -       |              |                         |
| POWER SUPPLY                                     |   |                  | ±4 <i>E</i>           |                       |            |         |              |            |         |              | V                       |
| Rated Voltage<br>Voltage Range                   |   | ±11              | ±15                   | ±20                   |            |         |              |            |         |              | l v                     |
| Quiescent Current                                |   | ] <sup>±11</sup> | ±5.5                  | ±20<br>±6.0           |            | *       | *            |            | *       |              | mA                      |
|  |   |                  | _⊥ა.ა                 | ±0.0                  |            | *       | *            |            | *       |              | IIIA                    |
| TEMPERATURE RANGE                                |   |                  |                       | . 70                  | 0.5        |         |              |            |         | .405         |                         |
| Specification                                    |   | 0                |                       | +70                   | -25<br>EE  |         | +85          | -55<br>55  |         | +125         | °C<br>°C                |
| Operating<br>Storage                             |   | -25<br>-25       |                       | +85<br>+85            | –55<br>–65 |         | +125<br>+150 | -55<br>-65 |         | +125<br>+150 | °C                      |
| Otorage  | l   | -23              |                       | +00                   | -05        |         | +130         | -00        | 1       | 1 +130       | I                       |

<sup>\*</sup> Specification the same as VFC32KP.

NOTES: (1) A 25% duty cycle (0.25mA input current) is recommended for best linearity. (2) Adjustable to zero. See Offset and Gain Adjustment section. (3) Linearity error is specified at any operating frequency from the straight line intersecting 90% of full scale frequency and 0.1% of full scale frequency. See Discussion of Specifications section. Above 200kHz, it is recommended all grades be operated below +85°C. (4) ±0.015% of FSR for negative inputs shown in Figure 5. Positive inputs are shown in Figure 1. (5) FSR = Full Scale Range (corresponds to full scale frequency and full scale input voltage). (6) Exclusive of external components' drift. (7) Positive drift is defined to be increasing frequency with increasing temperature. (8) For operations above 200kHz up to 500kHz, see Discussion of Specifications and Installation and Operation sections. (9) One pulse of new frequency plus 1µs.

#### **ABSOLUTE MAXIMUM RATINGS**

| Supply Voltage             | ±22V           |
|----------------------------|----------------|
| Output Sink Current (Fout) | 50mA           |
| Output Current (VOUT)      | +20mA          |
| Input Voltage, -Input      | ±Supply        |
| Input Voltage, +Input      | ±Supply        |
| Comparator Input           | ±Supply        |
| Storage Temperature Range: |                |
| VFC32BM, SM                | 65°C to +150°C |
| VFC32KP, KU                | –25°C to +85°C |
|                            |                |

### **PACKAGE/ORDERING INFORMATION**

| PRODUCT | PACKAGE            | PACKAGE<br>DRAWING<br>NUMBER <sup>(1)</sup> | TEMPERATURE<br>RANGE |
|---------|--------------------|---|----------------------|
| VFC32KP | 14-Pin Plastic DIP | 010   | 0°C to 70°C          |
| VFC32BM | TO-100 Metal       | 007   | –25°C to +85°C       |
| VFC32SM | TO-100 Metal       | 007   | -55°C to +125°C      |
| VFC32KU | SO-14 SOIC         | 235   | 0°C to +70°C         |

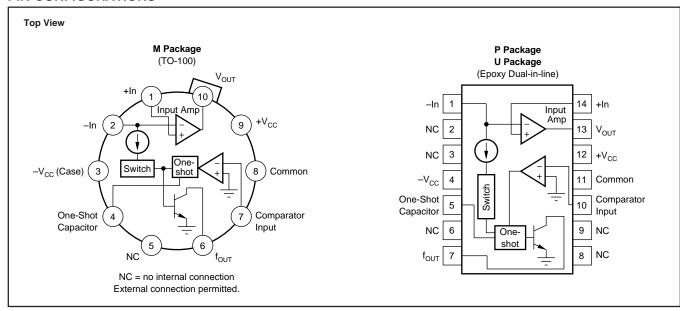
NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix C of Burr-Brown IC Data Book.

# ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

#### **PIN CONFIGURATIONS**



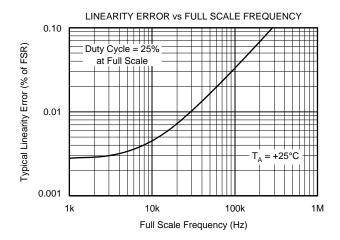
The information provided herein is believed to be reliable; however, BURR-BROWN assumes no responsibility for inaccuracies or omissions. BURR-BROWN assumes no responsibility for the use of this information, and all use of such information shall be entirely at the user's own risk. Prices and specifications are subject to change without notice. No patent rights or licenses to any of the circuits described herein are implied or granted to any third party. BURR-BROWN does not authorize or warrant any BURR-BROWN product for use in life support devices and/or systems.

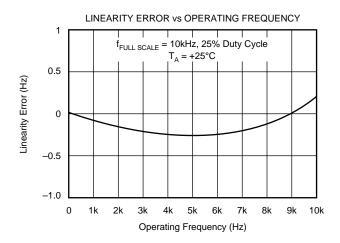
3

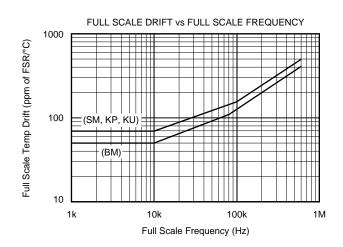
VFC32

# **TYPICAL PERFORMANCE CURVES**

At  $T_{\text{A}}$  = +25°C and  $V_{\text{CC}}$  =  $\pm 15 \text{V},$  unless otherwise noted.







4

# APPLICATION INFORMATION

Figure 1 shows the basic connection diagram for frequency-to-voltage conversion.  $R_1$  sets the input voltage range. For a 10V full-scale input, a  $40k\Omega$  input resistor is recommended. Other input voltage ranges can be achieved by changing the value of  $R_1$ .

$$R_1 = \frac{V_{FS}}{0.25 \text{mA}} \tag{1}$$

 $R_1$  should be a metal film type for good stability. Manufacturing tolerances can produce approximately  $\pm 10\%$  variation in output frequency. Full-scale output frequency can be trimmed by adjusting the value of  $R_1$ —see Figure 3.

The full-scale output frequency is determined by C<sub>1</sub>. Values shown in Figure 1 are for a full-scale output frequency of 10kHz. Values for other full-scale frequencies can be read from Figure 2. Any variation in C<sub>1</sub>—tolerance, temperature drift, aging—directly affect the output frequency. Ceramic NPO or silver-mica types are a good choice.

For full-scale frequencies above 200kHz, use larger capacitor values as indicated in Figure 2, with  $R_1 = 20k\Omega$ .

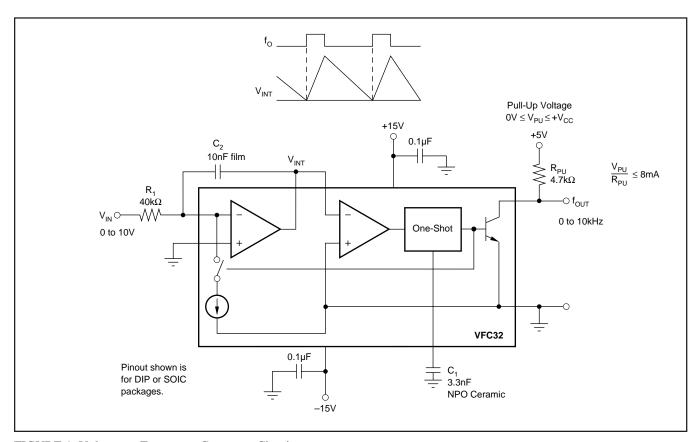
The value of the integrating capacitor, C<sub>2</sub>, does not directly influence the output frequency, but its value must be chosen within certain bounds. Values chosen from Figure 2 produce

approximately 2.5Vp-p integrator voltage waveform. If  $C_2$ 's value is made too low, the integrator output voltage can exceed its linear output swing, resulting in a nonlinear response. Using  $C_2$  values larger than shown in Figure 2 is acceptable.

Accuracy or temperature stability of C<sub>2</sub> is not critical because its value does not directly affect the output frequency. For best linearity, however, C<sub>2</sub> should have low leakage and low dielectric absorption. Polycarbonate and other film capacitors are generally excellent. Many ceramic types are adequate, but some low-voltage ceramic capacitor types may degrade nonlinearity. Electrolytic types are not recommended.

#### FREQUENCY OUTPUT PIN

The frequency output terminal is an open-collector logic output. A pull-up resistor is usually connected to a 5V logic supply to create standard logic-level pulses. It can, however, be connected to any power supply up to  $+V_{\rm CC}$ . Output pulses have a constant duration and positive-going during the one-shot period. Current flowing in the open-collector output transistor returns through the Common terminal. This terminal should be connected to logic ground.



5

FIGURE 1. Voltage-to-Frequency Converter Circuit.

VFC32

#### FREQUENCY-TO-VOLTAGE CONVERSION

Figure 4 shows the VFC32 connected as a frequency-to-voltage converter. The capacitive-coupled input network  $C_3$ ,  $R_6$  and  $R_7$  allow standard 5V logic levels to trigger the comparator input. The comparator triggers the one-shot on the falling edge of the frequency input pulses. Threshold voltage of the comparator is approximately -0.7V. For frequency input waveforms less than 5V logic levels, the  $R_6/R_7$  voltage divider can be adjusted to a lower voltage to assure that the comparator is triggered.

The value of  $C_1$  is chosen from Figure 2 according to the full-scale input frequency.  $C_2$  smooths the output voltage waveform. Larger values of  $C_2$  reduce the ripple in the output voltage. Smaller values of  $C_2$  allow the output voltage to settle faster in response to a change in input frequency. Resistor  $R_1$  can be trimmed to achieve the desired output voltage at the full-scale input frequency.

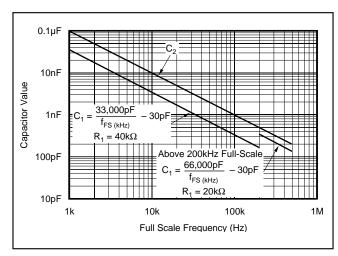


FIGURE 2. Capacitor Value Selection.

#### PRINCIPLES OF OPERATION

The VFC32 operates on a principle of charge balance. The signal input current is equal to  $V_{\rm IN}/R_1$ . This current is integrated by input op amp and  $C_2$ , producing a downward ramping integrator output voltage. When the integrator output ramps to the threshold of the comparator, the one-shot is triggered. The 1mA reference current is switched to the integrator input during the one-shot period, causing the integrator output ramp upward. After the one-shot period, the integrator again ramps downward.

The oscillation process forces a long-term balance of charge (or average current) between the input signal current and the reference current. The equation for charge balance is:

$$I_{IN} = I_{R(AVERAGE)}$$
 (2)

$$\frac{V_{IN}}{R_1} = f_O t_{OS} (1mA) \tag{3}$$

Where:

 $f_{o}$  is the output frequency  $t_{os}$  is the one-shot period, equal to  $t_{os} = 7500 \text{ C}_{1} \text{ (Farads)}$  (4)

The values suggested for  $R_1$  and  $C_1$  are chosen to produce a 25% duty cycle at full-scale frequency output. For full-scale frequencies above 200kHz, the recommended values produce a 50% duty cycle.

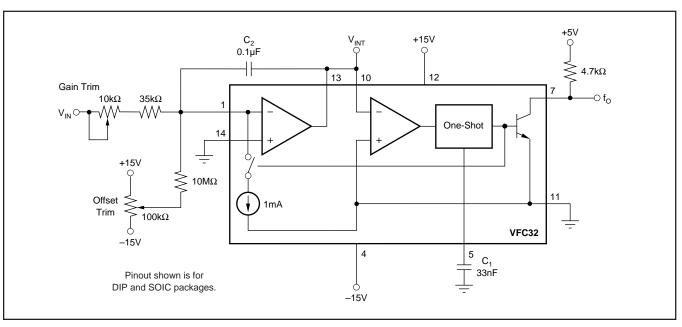


FIGURE 3. Gain and Offset Voltage Trim Circuit.

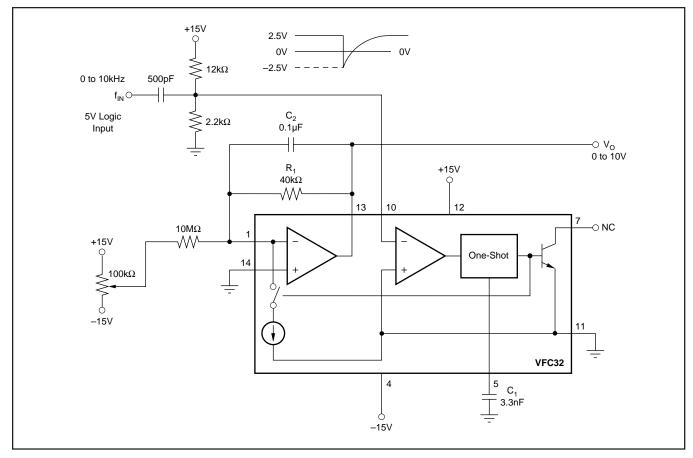
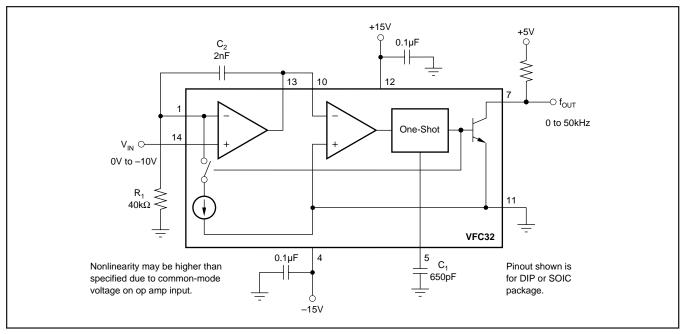


FIGURE 4. Frequency-to-Voltage Converter Circuit.



7

FIGURE 5. V/F Converter—Negative Input Voltage.





i.com 16-Feb-2009

#### PACKAGING INFORMATION

| Orderable Device | Status <sup>(1)</sup> | Package<br>Type | Package<br>Drawing | Pins | Package<br>Qty | e Eco Plan <sup>(2)</sup> | Lead/Ball Finish | MSL Peak Temp <sup>(3)</sup> |
|------------------|-----------------------|-----------------|--------------------|------|----------------|---------------------------|------------------|------------------------------|
| VFC32BM          | OBSOLETE              | TO-100          | LME                | 10   |                | TBD                       | Call TI          | Call TI                      |
| VFC32KP          | ACTIVE                | PDIP            | N                  | 14   | 25             | Green (RoHS & no Sb/Br)   | CU NIPDAU        | N / A for Pkg Type           |
| VFC32KPG4        | ACTIVE                | PDIP            | N                  | 14   | 25             | Green (RoHS & no Sb/Br)   | CU NIPDAU        | N / A for Pkg Type           |
| VFC32KU          | ACTIVE                | SOIC            | D                  | 14   | 50             | Green (RoHS & no Sb/Br)   | CU NIPDAU        | Level-3-260C-168 HR          |
| VFC32KU/2K5      | ACTIVE                | SOIC            | D                  | 14   | 2500           | Green (RoHS & no Sb/Br)   | CU NIPDAU        | Level-3-260C-168 HR          |
| VFC32KU/2K5G4    | ACTIVE                | SOIC            | D                  | 14   | 2500           | Green (RoHS & no Sb/Br)   | CU NIPDAU        | Level-3-260C-168 HR          |
| VFC32KUE4        | ACTIVE                | SOIC            | D                  | 14   | 50             | Green (RoHS & no Sb/Br)   | CU NIPDAU        | Level-3-260C-168 HR          |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free** (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

# PACKAGE MATERIALS INFORMATION

www.ti.com 20-Jul-2010

# TAPE AND REEL INFORMATION





| A0 | Dimension designed to accommodate the component width     |
|----|---|
| B0 | Dimension designed to accommodate the component length    |
| K0 | Dimension designed to accommodate the component thickness |
| W  | Overall width of the carrier tape                         |
| P1 | Pitch between successive cavity centers                   |

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



#### \*All dimensions are nominal

| Device      | Package<br>Type | Package<br>Drawing |    |      | Reel<br>Diameter<br>(mm) | Reel<br>Width<br>W1 (mm) | A0<br>(mm) | B0<br>(mm) | K0<br>(mm) | P1<br>(mm) | W<br>(mm) | Pin1<br>Quadrant |
|-------------|-----------------|--------------------|----|------|--------------------------|--------------------------|------------|------------|------------|------------|-----------|------------------|
| VFC32KU/2K5 | SOIC            | D                  | 14 | 2500 | 330.0                    | 16.4                     | 6.5        | 9.0        | 2.1        | 8.0        | 16.0      | Q1               |

**PACKAGE MATERIALS INFORMATION** 

www.ti.com 20-Jul-2010



#### \*All dimensions are nominal

| Device      | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| VFC32KU/2K5 | SOIC         | D               | 14   | 2500 | 346.0       | 346.0      | 33.0        |

#### IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

| Products                    |                        | Applications                 |                                   |
|-----------------------------|------------------------|------------------------------|-----------------------------------|
| Amplifiers                  | amplifier.ti.com       | Audio                        | www.ti.com/audio                  |
| Data Converters             | dataconverter.ti.com   | Automotive                   | www.ti.com/automotive             |
| DLP® Products               | www.dlp.com            | Communications and Telecom   | www.ti.com/communications         |
| DSP                         | <u>dsp.ti.com</u>      | Computers and<br>Peripherals | www.ti.com/computers              |
| Clocks and Timers           | www.ti.com/clocks      | Consumer Electronics         | www.ti.com/consumer-apps          |
| Interface                   | interface.ti.com       | Energy                       | www.ti.com/energy                 |
| Logic                       | logic.ti.com           | Industrial                   | www.ti.com/industrial             |
| Power Mgmt                  | power.ti.com           | Medical                      | www.ti.com/medical                |
| Microcontrollers            | microcontroller.ti.com | Security                     | www.ti.com/security               |
| RFID                        | www.ti-rfid.com        | Space, Avionics & Defense    | www.ti.com/space-avionics-defense |
| RF/IF and ZigBee® Solutions | www.ti.com/lprf        | Video and Imaging            | www.ti.com/video                  |
|                             |                        | Wireless                     | www.ti.com/wireless-apps          |