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.

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# SPECIFICATIONS

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

## 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 $+85^\circ C$.
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. Excessive 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 1 ms.

### PARAMETER CONDITIONS

<table>
<thead>
<tr>
<th>PARAMETER (V/F CONVERTER)</th>
<th>$F_{OUT} = V_I / 7.5 R_1 C_1$</th>
<th>( F_{OUT} = 7.5 R_1 C_1 F_{IN} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Range(1)</td>
<td>Positive Input &gt;0 0.25mA x $R_1$</td>
<td>Negative Input &gt;0 –10</td>
</tr>
<tr>
<td>Bias Current</td>
<td>Inverting Input 20 100 nA</td>
<td>Noninverting Input 100 250 nA</td>
</tr>
<tr>
<td>Offset Voltage(2)</td>
<td>Offset Voltage(2) 1 4</td>
<td>Differential Impedance 300</td>
</tr>
<tr>
<td>Common-mode Impedance</td>
<td>300</td>
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### ACCURACY

<table>
<thead>
<tr>
<th>PARAMETER(3)</th>
<th>Linearity Error</th>
<th>Offset Error</th>
<th>Gain Error</th>
<th>Gain Drift(6)</th>
<th>Full Scale Drift</th>
<th>Power Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>$0.01Hz \leq \text{Oper}$</td>
<td>$\pm0.015$</td>
<td>$\pm0.010$</td>
<td>$\pm3$ ppm of FSR</td>
<td>$\pm70$ ppm of FSR°C</td>
<td>$\pm0.015$</td>
</tr>
<tr>
<td>Frequency</td>
<td>$0.1Hz \leq \text{Oper}$</td>
<td>$\pm0.025$</td>
<td>$\pm0.05$</td>
<td>$\pm5$ ppm of FSR</td>
<td>$\pm70$ ppm of FSR°C</td>
<td>$\pm0.005$</td>
</tr>
<tr>
<td></td>
<td>$0.5Hz \leq \text{Oper}$</td>
<td>$\pm0.05$</td>
<td>$\pm0.05$</td>
<td>$\pm7$ ppm of FSR</td>
<td>$\pm70$ ppm of FSR°C</td>
<td>$\pm0.015$</td>
</tr>
<tr>
<td></td>
<td>$\leq 10kHz$</td>
<td>$\leq 0.005$</td>
<td>$\leq 0.010$</td>
<td>$\leq 0.025$</td>
<td>$\leq 0.05$</td>
<td>$\leq 0.015$</td>
</tr>
<tr>
<td></td>
<td>$\leq 100kHz$</td>
<td>$\leq 0.025$</td>
<td>$\leq 0.05$</td>
<td>$\leq 0.3$ ppm of FSR°C</td>
<td>$\leq 0.3$ ppm of FSR°C</td>
<td>$\leq 0.025$</td>
</tr>
<tr>
<td></td>
<td>$\leq 500kHz$</td>
<td>$\leq 0.05$</td>
<td>$\leq 0.05$</td>
<td>$\leq 0.5$ ppm of FSR°C</td>
<td>$\leq 0.5$ ppm of FSR°C</td>
<td>$\leq 0.05$</td>
</tr>
</tbody>
</table>

### POWER SUPPLY

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>VFC32KP, KU</th>
<th>VFC32BM</th>
<th>VFC32SM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiescent Current</td>
<td>$-5.5 \pm 0.6$ mA</td>
<td>$-5.5 \pm 0.6$ mA</td>
<td>$-5.5 \pm 0.6$ mA</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>$+25$ °C</td>
<td>$+25$ °C</td>
<td>$+25$ °C</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>$-25$ °C</td>
<td>$-25$ °C</td>
<td>$-25$ °C</td>
</tr>
</tbody>
</table>

* Specification the same as VFC32KP.
**ABSOLUTE MAXIMUM RATINGS**

- Supply Voltage: ±22V
- Output Sink Current ($I_{OUT}$): 50mA
- Output Current ($I_{OUT}$): +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**

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>PACKAGE</th>
<th>PACKAGE DRAWING NUMBER</th>
<th>TEMPERATURE RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>VFC32KP</td>
<td>14-Pin Plastic DIP</td>
<td>010</td>
<td>0°C to 70°C</td>
</tr>
<tr>
<td>VFC32BM</td>
<td>TO-100 Metal</td>
<td>007</td>
<td>–25°C to +85°C</td>
</tr>
<tr>
<td>VFC32SM</td>
<td>TO-100 Metal</td>
<td>007</td>
<td>–55°C to +125°C</td>
</tr>
<tr>
<td>VFC32KU</td>
<td>SO-14 SOIC</td>
<td>235</td>
<td>0°C to +70°C</td>
</tr>
</tbody>
</table>

**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**

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TYPICAL PERFORMANCE CURVES

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

- **LINEARITY ERROR vs FULL SCALE FREQUENCY**
  - Duty Cycle = 25%
  - $T_A = +25^\circ C$

- **LINEARITY ERROR vs OPERATING FREQUENCY**
  - $f_{FULL SCALE} = 10kHz$, 25% Duty Cycle
  - $T_A = +25^\circ C$

- **FULL SCALE DRIFT vs FULL SCALE FREQUENCY**
  - Full Scale Temp Drift (ppm of FSR/°C)
  - (SM, KP, KU)
  - (BM)
**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 \( R_1 \):

\[
R_1 = \frac{V_{FS}}{0.25mA}
\]  
(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 \( C_1 \). 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 \( C_1 \)—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, \( C_2 \), 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 \( C_2 \) is not critical because its value does not directly affect the output frequency. For best linearity, however, \( C_2 \) 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 \(+V_{CC}\). 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.

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![FIGURE 1. Voltage-to-Frequency Converter Circuit.](image-url)
**PRINCIPLES OF OPERATION**

The VFC32 operates on a principle of charge balance. The signal input current is equal to $V_{IN}/R_1$. 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:

$$I_{IN} = I_{R(AVERAGE)}$$  \hspace{1cm} (2)

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

Where:
- $f_O$ is the output frequency
- $t_{OS}$ is the one-shot period, equal to $t_{OS} = 7500 C_1$ (Farads)

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 4. Frequency-to-Voltage Converter Circuit.

FIGURE 5. V/F Converter—Negative Input Voltage.
## PACKAGING INFORMATION

<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status (1)</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Lead finish/ Ball material (2)</th>
<th>MSL Peak Temp (3)</th>
<th>Op Temp (°C)</th>
<th>Device Marking (4/5)</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>VFC32KP</td>
<td>ACTIVE</td>
<td>PDIP</td>
<td>N</td>
<td>14</td>
<td>25</td>
<td>RoHS &amp; Green</td>
<td>N / A for Pkg Type</td>
<td>0 to 70</td>
<td>VFC32KP</td>
<td>Samples</td>
</tr>
<tr>
<td>VFC32KPG4</td>
<td>ACTIVE</td>
<td>PDIP</td>
<td>N</td>
<td>14</td>
<td>25</td>
<td>RoHS &amp; Green</td>
<td>N / A for Pkg Type</td>
<td>0 to 70</td>
<td>VFC32KP</td>
<td>Samples</td>
</tr>
<tr>
<td>VFC32KU</td>
<td>ACTIVE</td>
<td>SOIC</td>
<td>D</td>
<td>14</td>
<td>50</td>
<td>RoHS &amp; Green</td>
<td>Level-3-260C-168 HR</td>
<td>0 to 70</td>
<td>VFC32KU</td>
<td>Samples</td>
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<tr>
<td>VFC32KU/2K5</td>
<td>ACTIVE</td>
<td>SOIC</td>
<td>D</td>
<td>14</td>
<td>2500</td>
<td>RoHS &amp; Green</td>
<td>Level-3-260C-168 HR</td>
<td>0 to 70</td>
<td>VFC32KU</td>
<td>Samples</td>
</tr>
<tr>
<td>VFC32KUE4</td>
<td>ACTIVE</td>
<td>SOIC</td>
<td>D</td>
<td>14</td>
<td>50</td>
<td>RoHS &amp; Green</td>
<td>Level-3-260C-168 HR</td>
<td>0 to 70</td>
<td>VFC32KU</td>
<td>Samples</td>
</tr>
</tbody>
</table>

(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) **RoHS**: TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, “RoHS” products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free". **RoHS Exempt**: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
- **Green**: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.
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TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

- Reel Diameter
- Reel Width (W1)

**TAPE DIMENSIONS**

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

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**

- Sprocket Holes
- Pocket Quadrants
- User Direction of Feed

*All dimensions are nominal*

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Reel Diameter (mm)</th>
<th>Reel Width (W1 mm)</th>
<th>A0 (mm)</th>
<th>B0 (mm)</th>
<th>K0 (mm)</th>
<th>P1 (mm)</th>
<th>W (mm)</th>
<th>Pin1 Quadrant</th>
</tr>
</thead>
<tbody>
<tr>
<td>VFC32KU/2K5</td>
<td>SOIC</td>
<td>D</td>
<td>14</td>
<td>2500</td>
<td>330.0</td>
<td>16.4</td>
<td>6.5</td>
<td>9.0</td>
<td>2.1</td>
<td>8.0</td>
<td>16.0</td>
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**TAPE AND REEL BOX DIMENSIONS**

*All dimensions are nominal*

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Height (mm)</th>
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</thead>
<tbody>
<tr>
<td>VFC32KU/2K5</td>
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# PACKAGE MATERIALS INFORMATION

## TUBE

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<thead>
<tr>
<th>Device</th>
<th>Package Name</th>
<th>Package Type</th>
<th>Pins</th>
<th>SPQ</th>
<th>L (mm)</th>
<th>W (mm)</th>
<th>T (µm)</th>
<th>B (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VFC32KP</td>
<td>N</td>
<td>PDIP</td>
<td>14</td>
<td>25</td>
<td>506</td>
<td>13.97</td>
<td>11230</td>
<td>4.32</td>
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<tr>
<td>VFC32KPG4</td>
<td>N</td>
<td>PDIP</td>
<td>14</td>
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<td>506</td>
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<td>SOIC</td>
<td>14</td>
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<td>50</td>
<td>506.6</td>
<td>8</td>
<td>3940</td>
<td>4.32</td>
</tr>
</tbody>
</table>

*All dimensions are nominal*

Dimensions:
- **L** - Tube length
- **T** - Tube height
- **W** - Tube width
- **B** - Alignment groove width

*All dimensions are nominal*
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