

LB-45

LB-45 Frequency-to-Voltage Converter uses Sample-and-Hold to Improve Response and Ripple



Literature Number: SNOA698

Frequency-to-Voltage Converter uses Sample-and-Hold to Improve Response and Ripple

National Semiconductor
Linear Brief 45
April 1979



Frequency-to-Voltage Converter uses Sample-and-Hold to Improve Response and Ripple

Most frequency-to-voltage (F-to-V) converters suffer from the classical tradeoff of ripple versus speed of response. For example, the basic F-to-V converter shown below has 13 mVp-p of ripple, and a rather slow 0.6 second settling time, when C_{FILTER} is 1 μ F. If you want less ripple than that, the response time will be even slower. If you want quicker response, it is easy to decrease C_{FILTER} , but the ripple will increase by the same factor.

The improved circuit in Figure 2 makes an end-run around these compromises. A low-cost sample-and-hold circuit

such as LF398 can sample the F-to-V's output at the peak of its ripple, and hold it until the next cycle. The LF398 has fairly low output ripple (rms) but it does have some short duration noise spikes and glitches which can be removed easily with a simple output filter. The ripple at the output of the active filter V6 is smaller than 1 mV peak, but the settling time for a step change of input frequency is only 60 ms, or ten times quicker than the "basic" FVC with $C_{FILTER} = 1 \mu$ F.

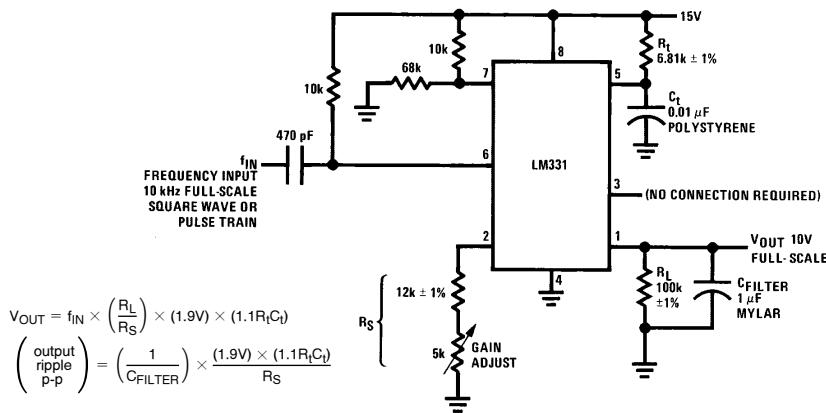


FIGURE 1. Basic Frequency-to-Voltage Converter

TL/H/8494-1

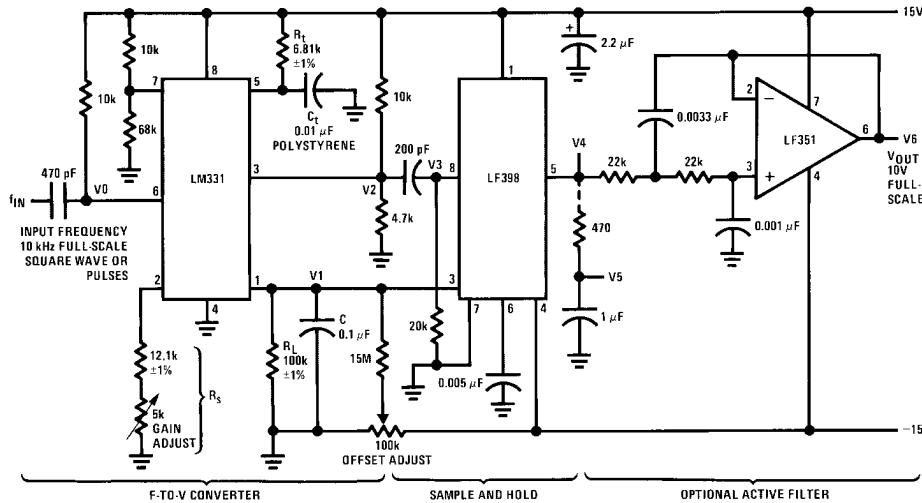


FIGURE 2. Improved F-to-V Converter Using Sample-and-Hold

TL/H/8494-2

LB-45

DETAILS OF OPERATION (Refer to Figure 3, Waveforms)

When the input frequency waveform has a negative-going transition, pin 6 of the LM331 is driven momentarily lower than the 13V threshold voltage at pin 7. This initiates a timing cycle controlled by the R_t and C_t at pin 5, and also causes a transition from +5V to 0V at pin 3, (the normal VFC logic output) which is usually left unused in F-to-V operation.

During the timing cycle ($t = 1.1 \times R_t \times C_t = 75 \mu s$, for the example shown) a precision current source $i = 1.9 V/R_S$ flows out of pin 1 of the LM331, and charges V1 up to a value slightly higher than the average DC value of V1. At the end of the timing cycle, V1 stops charging up, and also V2 rises. The 10 k Ω pull-up resistor is coupled (through the 200 pF capacitor) to V3, and causes the LF398 to *sample* for about 5 μs . Then the LF398 goes back into *hold*. This entire operation is repeated at the same frequency as f_{IN} . The average voltage at V1 will be the same 10V full scale, according to the same formula of Figure 1. And the peak-to-peak ripple can be computed as 65 mV peak, 130 mVp-p, using the appropriate formula.

Now, the input to the sample-and-hold at pin 3 may have a 10.000V average DC value, but the output will be at 10.065V, because the sample occurs at the peak value of V1. Thus, to get an output with low offset, a 15 M Ω resistor is used to offset the V1 signal to a lower level. Trim the offset adjust pot to get $V_{OUT} = 1V$ at 1 kHz, and trim the gain adjust pot to get $V_{OUT} = 10V$ at 10 kHz (the interaction is minor), as measured at V4, V5, or V6. The rms value of the ripple at V4 is rather small, but the peak-to-peak ripple (spikes and glitches) may be excessive. A simple R-C filter can provide a filtered output at V5; or a simple active filter using an inexpensive LF351, will give sub-millivolt (peak) ripple at V6, with improved settling time and low output impedance.

This F-to-V converter will have a good linearity, better than 0.1%, but only from 10 kHz down to 500 Hz. Between 200 Hz and 20 Hz, V_{OUT} is not very proportional to f_{IN} . And at 0 Hz, the output will be indeterminate, because the sample-and-hold will never sample! However, there are many F-to-V applications where a 20:1 frequency range is adequate.

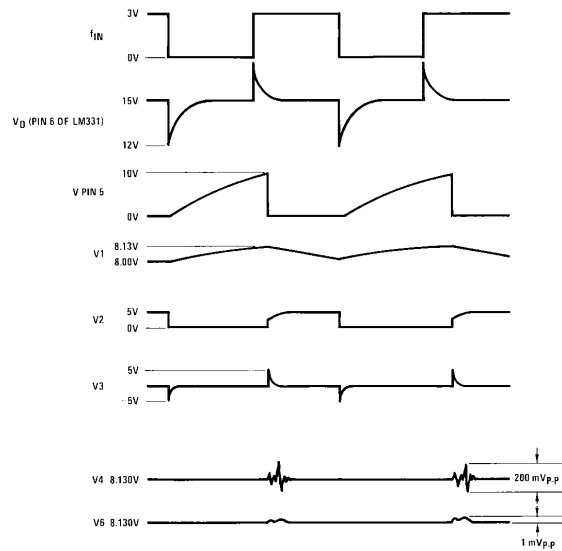


FIGURE 3. Waveforms, Improved F-to-V Converter

TL/H/8494-3

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



National Semiconductor Corporation
 1111 West Bardin Road
 Arlington, TX 76017
 Tel: 1(800) 272-9959
 Fax: 1(800) 737-7018

National Semiconductor Europe
 Fax: (+49) 0-180-530 85 86
 Email: onjwge@tevm2.nsc.com
 Deutsch Tel: (+49) 0-180-530 85 85
 English Tel: (+49) 0-180-532 78 32
 Français Tel: (+49) 0-180-532 93 58
 Italiano Tel: (+49) 0-180-534 16 80

National Semiconductor Hong Kong Ltd.
 19th Floor, Straight Block,
 Ocean Centre, 5 Canton Rd.
 Tsimshatsui, Kowloon
 Hong Kong
 Tel: (852) 2737-1600
 Fax: (852) 2736-9960

National Semiconductor Japan Ltd.
 Tel: 81-043-299-2309
 Fax: 81-043-299-2408

National does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.

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

Audio	www.ti.com/audio
Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
OMAP Mobile Processors	www.ti.com/omap
Wireless Connectivity	www.ti.com/wirelessconnectivity

Applications

Communications and Telecom	www.ti.com/communications
Computers and Peripherals	www.ti.com/computers
Consumer Electronics	www.ti.com/consumer-apps
Energy and Lighting	www.ti.com/energy
Industrial	www.ti.com/industrial
Medical	www.ti.com/medical
Security	www.ti.com/security
Space, Avionics and Defense	www.ti.com/space-avionics-defense
Transportation and Automotive	www.ti.com/automotive
Video and Imaging	www.ti.com/video

TI E2E Community Home Page

e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2011, Texas Instruments Incorporated