

### Introduction

The sample-and-hold or track-and-hold function is very widely used in linear systems. This function is readily available in modular, hybrid, and monolithic form.

All high quality sample-and-hold circuits must meet certain requirements:

1. The holding capacitor must charge up and settle to its final value as quickly as possible.
2. When holding, the leakage current at the capacitor must be as near zero as possible to minimize voltage drift with time.
3. Other sources of error must be minimized.

Design of a sample-and-hold involves a number of compromises in the above requirements. The amplifier or other device feeding the analog switch must have high current capability and be able to drive capacitive loads with stability. The analog switch must have both low ON resistance and extremely low OFF leakage currents. But, leakage currents of most analog switches (except the dielectrically isolated types) run to several hundred nanoamperes at elevated temperatures. The analog switch must have very low coupling between the digital input and analog output, because any spikes generated at the instant of turn-off will change the charge on the capacitor. The output amplifier must have extremely low bias current over the temperature range, and also must have low offset drift and sufficient slew rate.

Another design consideration is whether to make the input differential or single ended. A single ended sample/hold amplifier has a fixed gain, usually +1, so that it simply provides the sample/hold function. In contrast, a differential input sample-and-hold amplifier is designed to be configured with external feedback, just like an op amp. It may be used to form a filter, integrator, inverting or non-inverting amplifier with gain, etc. This allows the designer to combine any number of op amp signal conditioning circuits with the sample-and-hold function. All Intersil sample-and-hold amplifiers are designed with differential inputs to take advantage of this capability.

### The HA-2420/2425

The HA-2420/2425 is one of the most versatile monolithic sample-and-hold integrated circuits. A functional diagram is shown in Figure 1.

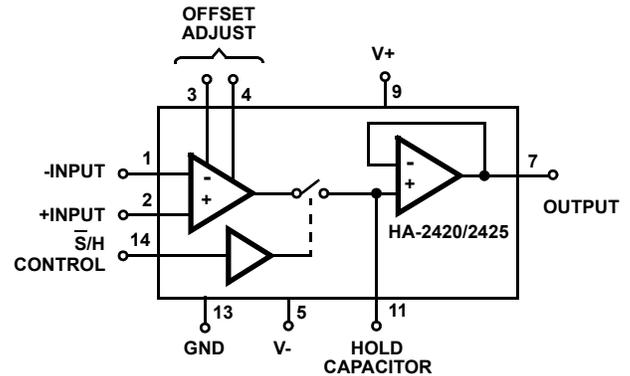


FIGURE 1. HA-2420/2425 FUNCTIONAL DIAGRAM

The input amplifier stage is a high performance operational amplifier with excellent slew rate, and the ability to drive high capacitance loads without instability. The switching element is a highly efficient bipolar transistor stage with extremely low leakage in the OFF condition. The output amplifier is a MOSFET input unity gain follower to achieve extremely low bias current.

MOSFET inputs are generally not used for DC amplifiers because their offset voltage drift is difficult to control. In this configuration, however, negative feedback is generally applied between the output and inputs of the entire device, and the effect of this offset drift at the inputs is divided by the open loop gain of the input amplifier stage.

### The HA-5320

The HA-5320 is a high speed monolithic sample/hold circuit which includes its own 100pF hold capacitor. Unlike the HA-2420/2425, this device utilizes an input transconductance amplifier and integrating output stage as shown in Figure 2. The hold capacitor is charged through a low leakage analog switch at the virtual ground node of the output amplifier. In this configuration, charge injection at the transition from sample to hold is constant over the entire input/output voltage range. Additional hold capacitance may be added to the HA-5320 for improved droop rage, at the expense of increased acquisition time.

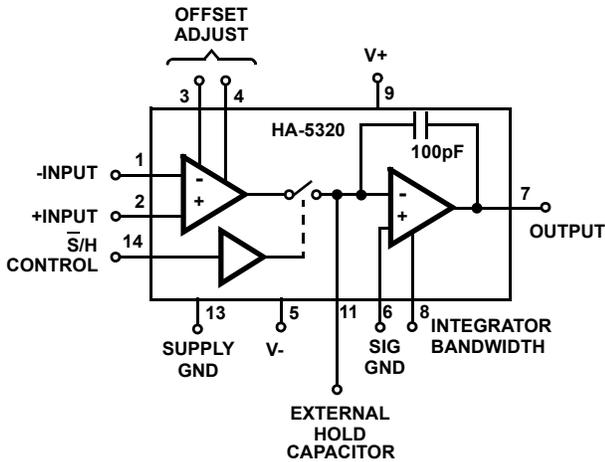


FIGURE 2. HA-5320 FUNCTIONAL DIAGRAM

### The HA-5330

The HA-5330 is a monolithic sample/hold amplifier optimized for very high speed performance, acquiring a 10V step to 0.01% in 500ns. Its circuit topology is similar to the HA-5320 (Figure 3), but there is no provision for external capacitance. The integrated 90pF capacitor provides excellent performance alone; external leakage paths and noise pickup are avoided in this design by not exposing the integrator input node to an external pin.

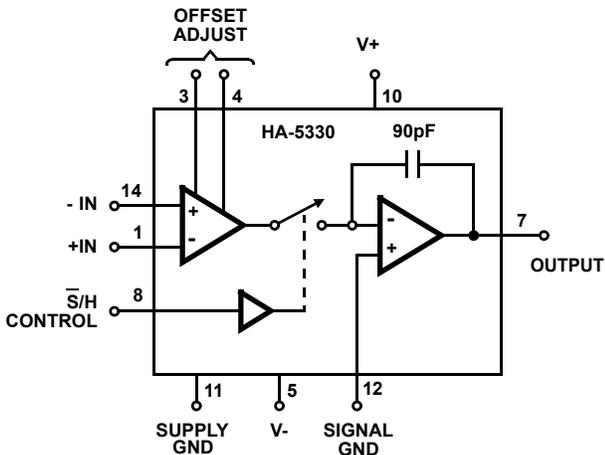


FIGURE 3. HA-5330 FUNCTIONAL DIAGRAM

### Sample-and-Hold Applications

A number of basic applications are shown on the following pages. These devices are exceptionally versatile, since they can be wired into any of the hundreds of feedback configurations possible with any operational amplifier. In many applications the device will replace both an operational amplifier and a sample-and-hold module.

The larger the value of the hold capacitor, the longer time it will hold the signal without excessive drift; however, it will also reduce the charging rate/slew rate and the amplifier bandwidth

during sampling. So, the capacitance value must be optimized for each particular application. Drift during holding tends to double for every 10°C rise in ambient temperature. The holding capacitor should have extremely high insulation resistance and low dielectric absorption-polystyrene (below +85°C), Teflon, or mica types are recommended.

For least drift during holding, leakage paths on the P.C. board and on the device package surface must be minimized. The output voltage is nearly equal to the voltage on  $C_H$  for the HA-2420. The output line may be used as a guard ring surrounding the line to  $C_H$ . Since the potentials are nearly equal, very low leakage currents will flow. The two package pins surrounding the  $C_H$  pin are not internally connected, and may be used as guard pins to reduce leakage on the package surface. A suggested P.C. guard ring layout is shown in Figure 4. The hold capacitor in the HA-5320 operates at virtual ground. For this device, a guard ring must be connected to the SIG GND terminal (pin 6) instead of output.

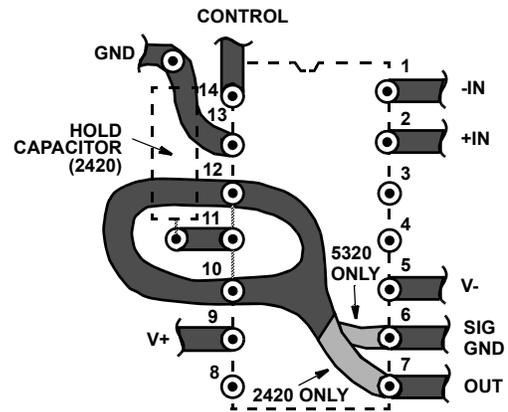


FIGURE 4. GUARD RING LAYOUT (BOTTOM VIEW)

Since the internal hold capacitor is not assessable in the HA-5330, no P.C. layout consideration to minimize leakage is necessary.

Although the hold capacitor is configured differently for the three sample/hold devices as shown in Figure 5, most applications are common to all. For simplicity, the hold capacitor has been excluded from circuit diagrams in the following examples and the S/H's are depicted as op amps with a sample/hold control. This symbol is intended to remind the user of the "op amp" capability of these devices.

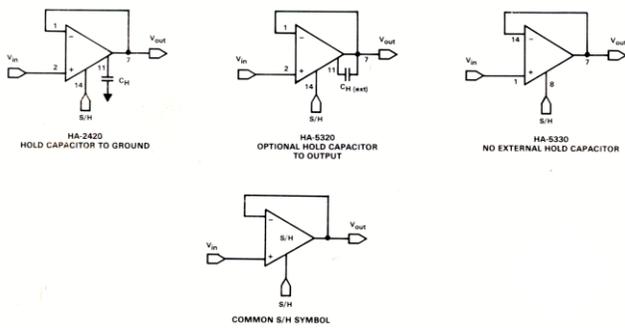


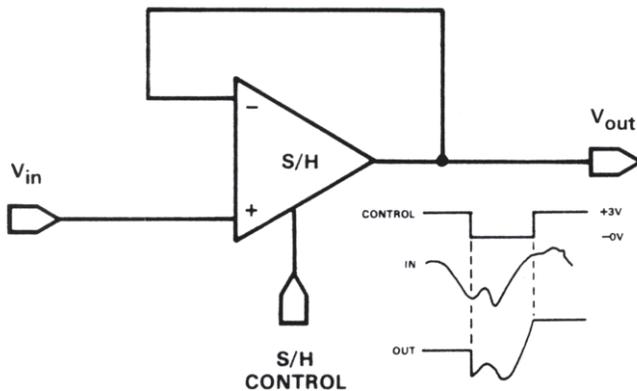
FIGURE 5. SIMPLIFIED S/H SYMBOL (UNITY GAIN CONFIGURATION)

### Application No. 1

Feedback is the same as a conventional op amp voltage follower which yields a unity gain, non-inverting output. This hookup also has a very high input impedance.

The only difference between a track-and-hold and sample-and-hold is the time period during which the switch is closed. In track-and-hold operation, the switch is closed for a relatively long period during which the output signal may change appreciably; the output will hold the level present at the instant the switch is opened. In sample-and-hold operation, the switch is closed only for the period of time necessary to fully charge the holding capacitor.

#### BASIC TRACK-AND-HOLD/SAMPLE-AND-HOLD



### Application No. 2

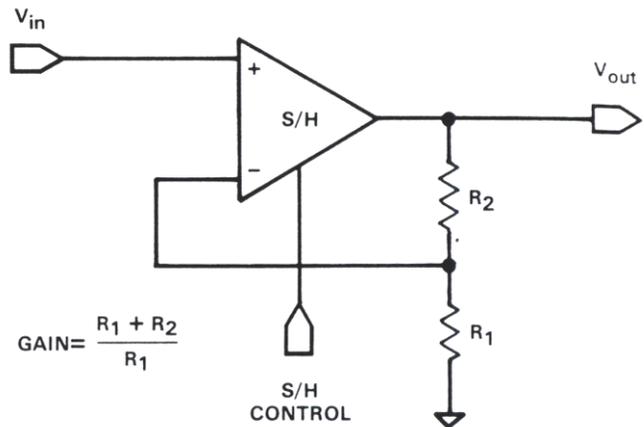
This is the standard non-inverting amplifier feedback circuit.

It illustrates one of the many ways in which a sample/hold amplifier may be used to perform both op amp and sampling functions, eliminating the need for a separate scaling amplifier and sample-and-hold module.

In general, it is usually best design practice to scale the gain such that the largest expected signal will give an output close to + or -10 volts. Drift current is essentially independent of

output level, and less percentage drift will occur in a given time for a larger output signal.

#### SAMPLE-AND-HOLD WITH GAIN

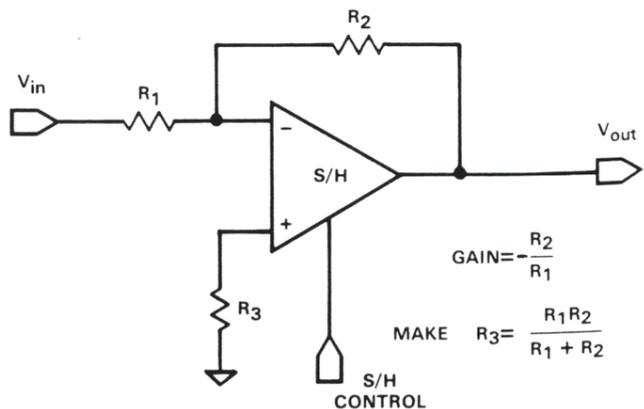


### Application No. 3

This illustrates another application in which the hookup versatility of a sample/hold often eliminates the need for a separate operational amplifier and sample-and-hold module. This hookup will have somewhat higher input to output feedthrough during "hold", than the non-inverting connection, since output impedance is the open-loop value during "hold", and feedthrough will be:

$$\frac{V_{IN}R_O}{R_1 + R_2 + R_O}$$

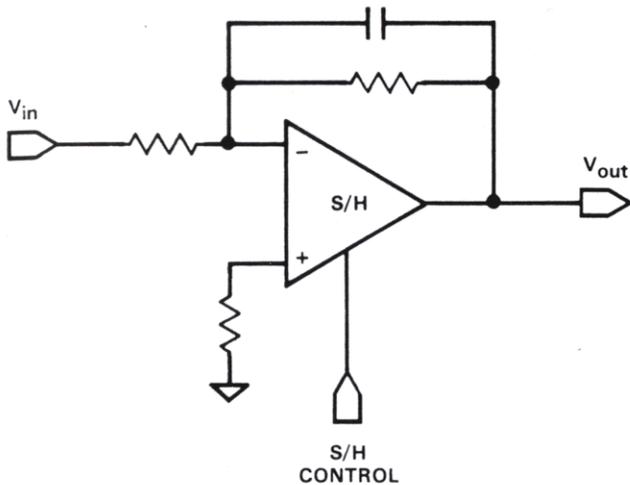
#### INVERTING SAMPLE-AND-HOLD



### Application No. 4

It is often required that a signal be filtered prior to sampling. This can be accomplished with only one device. Any of the inverting and non-inverting filters which can be built with op amps can be implemented. However, it is necessary that the sampling switch be closed for sufficient time for the filter to settle when active filter types are connected around the device.

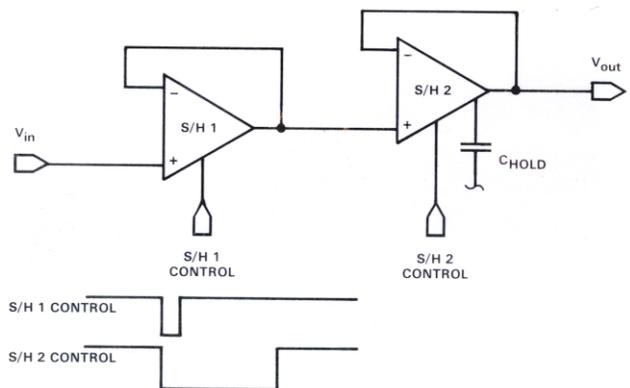
**FILTERED SAMPLE-AND-HOLD**



**Application No. 5**

Short sample times require a low value holding capacitor; while long, accurate hold times require a high value holding capacitor. So, achieving a very long hold with a short sample appears to be contradictory. However, it can be accomplished by cascading two S/H circuits, the first with a low value capacitor, the second with a high value. Then the second S/H can sample for as long a time as the first circuit can accurately hold the signal.

**CASCADE SAMPLE-AND-HOLD**



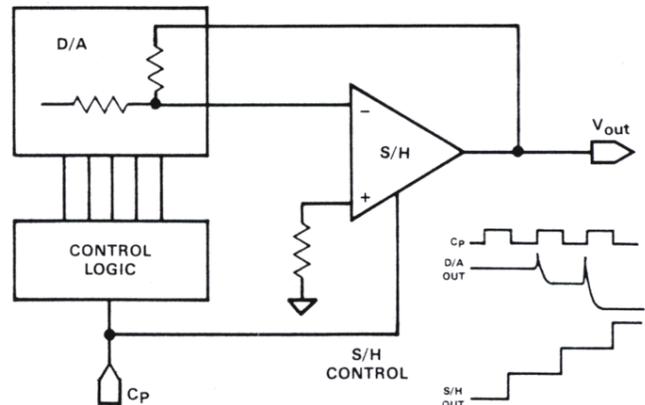
**Application No. 6**

The word "glitch" has been a universal slang expression among electronics people for an unwanted transient condition. In D to A converters, the word has achieved semi-official status for an output transient which occurs when the digital input address is changed.

In the illustration, the sample/hold amplifier does double duty, serving as a buffer amplifier as well as a glitch remover, delaying the output by 1/2 clock cycle.

The sample/hold may be used to remove many other types of "glitches" in a system. If a delayed sample pulse is required, this can be generated using a dual monostable multivibrator I.C.

**DE-GLITCHER**

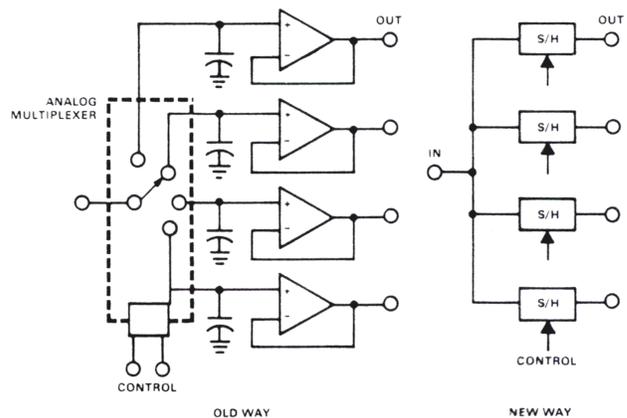


**Application No. 7**

This circuit reconstructs and separates analog signals which have been time division multiplexed.

The conventional method, shown on the left, has several restrictions, particularly when a short dwell time and a long, accurate hold time is required. The capacitors must charge from a low impedance source through the resistance and current limiting characteristics of the multiplexer. When holding, the high impedance lines are relatively long and subject to noise pickup and leakage. When FET input buffer amplifiers are used for low leakage, severe temperature offset errors are often introduced.

**DE-MULTIPLEXER**



**Application No. 8**

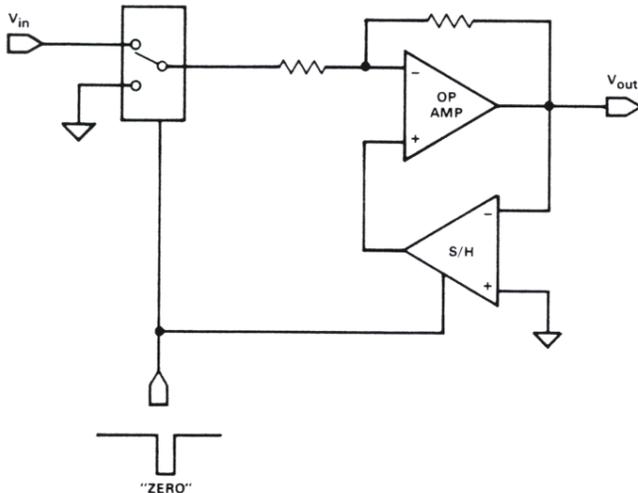
This basic circuit has widespread applications in instrumentation, A/D conversion, DVMs and DPMs to eliminate offset drift errors by periodically rezeroing the system.

Basically, the input is periodically grounded, the output offset is then sampled and fed back to cancel the error.

The system illustrated automatically zeros a high gain amplifier. Care in the actual design is necessary to assure that the zeroing loop is dynamically stable. A second sample-and-hold could be added in series with the output to remove the output discontinuity.

Many variations of this scheme are possible to suit the individual system.

**AUTOMATIC OFFSET ZEROING**

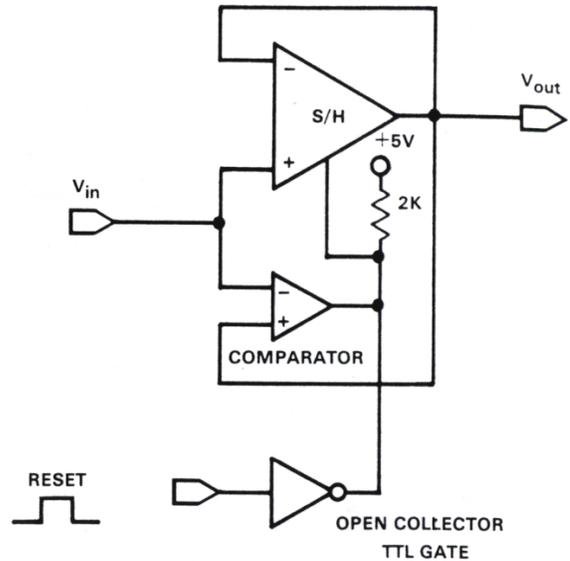


**Application No. 9**

This accurate, low drift peak detector circuit combines the basic sample-and-hold connection with a comparator. When the input signal level exceeds the voltage being stored in the S/H, the comparator trips, and a new sample of the input is taken. The S/H offset pot should be adjusted for a slight positive offset, so that the comparator will trip back when the new peak is acquired; otherwise the comparator would remain "on" and the S/H would follow the peak back down.

To make a negative peak detector, reverse the comparator inputs and adjust the S/H for a negative offset.

The reset function, which is difficult to achieve in other peak detector circuits, forces a new sample at the instantaneous input level.



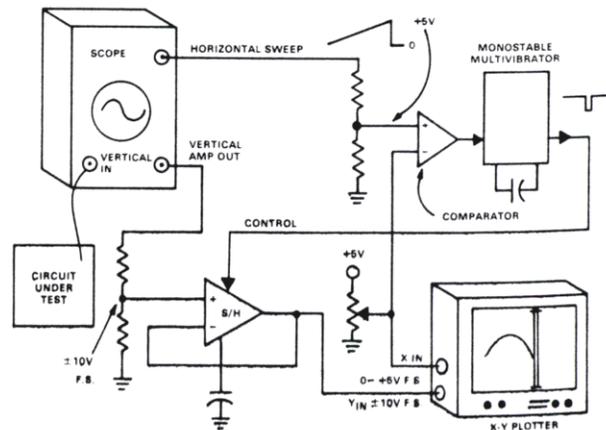
**Application No. 10**

This useful application illustrates how fast repetitive waveforms can be slowed down using sampling techniques. The input signal is much too fast to be tracked directly by the X-Y recorder, but sampling allows the recorder to be driven as slow as necessary.

To operate, the waveform is first synched in on the scope. Then the potentiometer connected to the recorder X input is slowly advanced, and the waveform will be reproduced. The S/H amplifier samples for a very short interval once each horizontal sweep of the scope. The sampling instant is determined by the potentiometer at the instant when the horizontal sweep waveform corresponds to the X position of the recorder.

This principle can be applied to many systems for waveform analysis, etc.

**PLOT HIGH SPEED WAVEFORMS WITH SAMPLING TECHNIQUES**



## Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.  
"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.  
"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.  
Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
6. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.  
(Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.  
(Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)



### SALES OFFICES

Renesas Electronics Corporation

<http://www.renesas.com>

Refer to "<http://www.renesas.com/>" for the latest and detailed information.

**Renesas Electronics America Inc.**  
1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.  
Tel: +1-408-432-8888, Fax: +1-408-434-5351

**Renesas Electronics Canada Limited**  
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3  
Tel: +1-905-237-2004

**Renesas Electronics Europe Limited**  
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K  
Tel: +44-1628-651-700, Fax: +44-1628-651-804

**Renesas Electronics Europe GmbH**  
Arcadiastrasse 10, 40472 Düsseldorf, Germany  
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

**Renesas Electronics (China) Co., Ltd.**  
Room 1709 Quantum Plaza, No.27 ZhichunLu, Haidian District, Beijing, 100191 P. R. China  
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

**Renesas Electronics (Shanghai) Co., Ltd.**  
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, 200333 P. R. China  
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

**Renesas Electronics Hong Kong Limited**  
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong  
Tel: +852-2265-6688, Fax: +852-2886-9022

**Renesas Electronics Taiwan Co., Ltd.**  
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan  
Tel: +886-2-8175-9600, Fax: +886-2-8175-9670

**Renesas Electronics Singapore Pte. Ltd.**  
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949  
Tel: +65-6213-0200, Fax: +65-6213-0300

**Renesas Electronics Malaysia Sdn.Bhd.**  
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia  
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

**Renesas Electronics India Pvt. Ltd.**  
No.777C, 100 Feet Road, HAL 2nd Stage, Indiranagar, Bangalore 560 038, India  
Tel: +91-80-67208700, Fax: +91-80-67208777

**Renesas Electronics Korea Co., Ltd.**  
17F, KAMCO Yangjae Tower, 262, Gangnam-daero, Gangnam-gu, Seoul, 06265 Korea  
Tel: +82-2-558-3737, Fax: +82-2-558-5338