

Introduction

Intersil Corporation has announced a new linear device, the HA-2400/HA-2405 Four Channel Operational Amplifier. This combines the functions of an analog switch and a high performance operational amplifier, and makes practical a large number of new linear circuit applications.

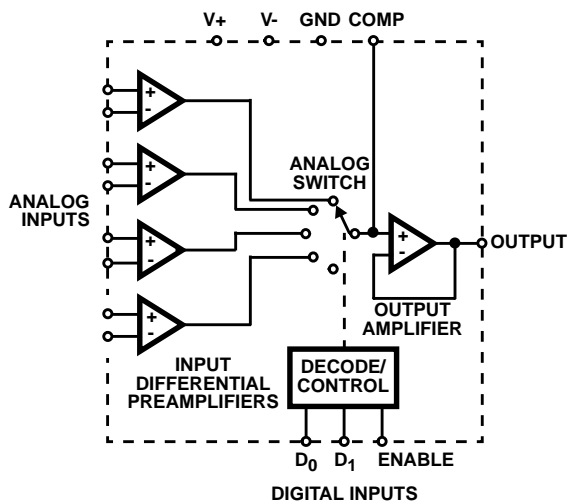


FIGURE 1.

A functional diagram of the HA-2400 is shown above. There are four preamplifier sections, one of which is selected through the DTL/TTL compatible inputs and connected to the output amplifier. The selected analog input terminals and the output terminal form a high performance operational amplifier.

In actuality, the circuit consists of four conventional op amp input circuits connected in parallel to a conventional op amp output circuit. The decode/control circuitry furnishes operating current only to the selected input section.

Circuit Connections

The digital inputs control the selection of the amplifier input channels in accordance with the following truth table:

D ₁	D ₀	ENABLE	CHANNEL 1	CHANNEL 2	CHANNEL 3	CHANNEL 4
L	L	H	ON	OFF	OFF	OFF
L	H	H	OFF	ON	OFF	OFF
H	L	H	OFF	OFF	ON	OFF
H	H	H	OFF	OFF	OFF	ON
L or H	L or H	L	OFF	OFF	OFF	OFF

0V ≤ L ≤ +0.8V

+2V ≤ H ≤ +5V

The digital inputs can be driven with any DTL or TTL circuit which uses a standard +5V supply.

Compensation

Frequency compensation for closed loop stability is recommended for closed loop gains less than 10. This is accomplished by connection of a single external capacitor from Pin 12 to AC ground (the V+ supply is recommended). The following table shows the minimum suggested compensation for various closed loop gains, with the resultant bandwidth and slew rate. Obviously, when the four channels are connected with different feedback networks, the channel with the lowest closed loop gain will govern the required compensation.

GAIN, V/V		C _{COMP} pF	BANDWIDTH (TYPICAL) (-3dB), MHz	SLEW RATE (TYPICAL) V/μs
NON-INVERTING	INVERTING			
1	-	15	8.0	15
2	1	7	8.0	20
3	2	4	8.0	22
5	4	3	6.0	25
8	7	2	5.0	30
>10	>9	0	40 ÷ GAIN	50

Compensation capacitors of greater value can be used to obtain lower bandwidth, greater phase margin, and reduced overshoot, at the expense of proportionately reduced slew rate.

External lead-lag networks could also be used to optimize bandwidth and/or slew rate at a particular gain.

Applications

Any circuit function which can be constructed using a conventional operational amplifier can also be constructed using any channel of the HA-2400. Similar or different networks can be wired from the output to each channel input pair. The device can therefore be used to select and condition different input signals, or to select between different op amp functions to be performed on a single input signal.

To wire a particular op amp function to a channel, simply connect the appropriate network between the two inputs for that channel and the common output in the same manner as in wiring a conventional op amp. It is often possible to design with fewer external components than would be required in wiring four separate op amps (see Application Numbers 2 and 3 on the following pages). It should be remembered that the networks for unselected channels may still constitute a load at the amplifier output and the signal input, as if the unselected input terminals were disconnected from the network.

If offset adjustment is required, it can generally be accomplished by resistive summation at either of the inputs for each channel (see Application Number 8).

The analog input terminals of the OFF channels draw the same bias current as the ON inputs. The maximum differential input voltage of these terminals must be observed and their voltage levels must never exceed the supply voltages.

When the Enable input is held low, all four input channels are disconnected from the output. When this occurs, the output voltage will generally slowly drift towards the negative supply. If a 0V output condition is required, one channel should be wired as a voltage follower with its positive input grounded.

The amplifier output impedance remains low, even when the inputs are disabled; so it is not generally practical to wire the outputs of two or more devices directly together. The compensation pins of two devices, however, could be wired together to produce a switch with one output and more than four input channels.

The voltage at the compensation pin is about 0.7V more positive than the output signal, but has a very high source impedance. Maximum current from this pin is about 300 μ A, which makes it a convenient point for limiting the output swing through clamping diodes and divider networks (see Application Number 13).

Even if the application only requires a single channel to be switched on and off, it is often more economical to use the HA-2400, rather than a separate analog switch and high performance op amp. Unused analog channel inputs should be grounded. Unused digital inputs may be wired to ground for a permanent "low" input, or either left open or wired to +5V for a permanent "high" input.

The circuits illustrated on the following pages are a few of the thousands of possible applications for the Four Channel Operational Amplifier. These will give the reader a general impression of how the units can be connected; and probably will help generate many other ideas for applications. Also included are some "challenges" for the reader to modify the illustrated designs to perform different functions.

Application No. 1

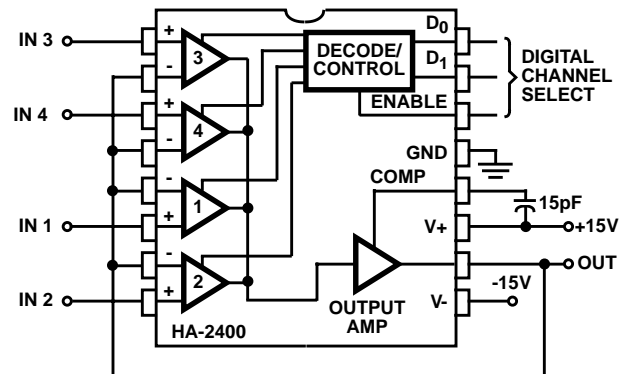


FIGURE 2. ANALOG MULTIPLEXER WITH BUFFERED INPUT AND OUTPUT

This circuit is used for analog signal selection or time division multiplexing. As shown, the feedback signal places the selected amplifier channel in a voltage follower (non-inverting unity gain) configuration, and provides very high input impedance and low output impedance. The single package replaces four input buffer amplifiers, four analog switches with decoding, and one output buffer amplifier.

For low level input signals, gain can be added to one or more channels by connecting the (-) inputs to a voltage divider between output and ground. Bandwidth is approximately 8MHz, and the output will slew from one level to another at about 15V/ μ s.

Expansion to multiplex 5 to 12 channels can be accomplished by connecting the compensation pins of two or three devices together, and using the output of only one of the devices. The Enable input on the unselected devices must be low.

Expansion to 16 or more channels is accomplished in a straightforward manner by connecting outputs of 4 four-channel multiplexers to the inputs of another four-channel multiplexer.

Differential signals can be handled by two identical multiplexers addressed in parallel.

Inverting amplifier configurations can also be used, but the feedback resistors may cause crosstalk from the output to unselected inputs.

Application No. 2

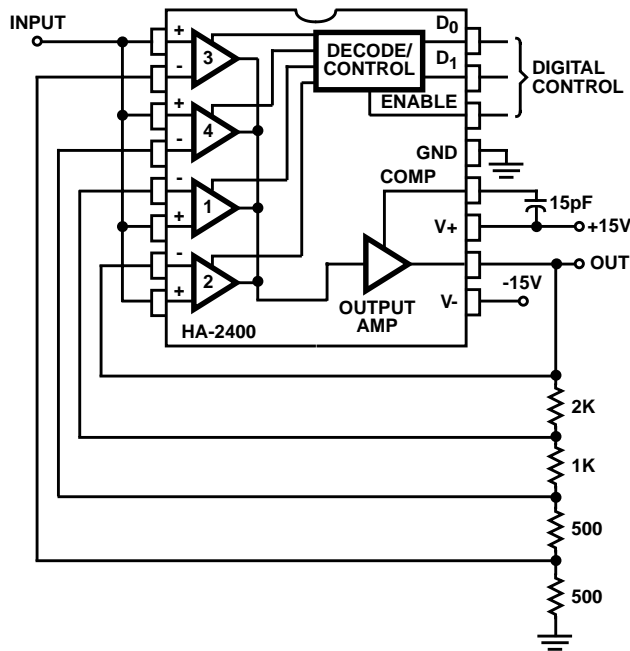


FIGURE 3. AMPLIFIER, NON-INVERTING PROGRAMMABLE GAIN

This is a non-inverting amplifier configuration with feedback resistors chosen to produce a gain of 0, 1, 2, 4, or 8 depending on the Digital Control inputs.

Comparators at the output could be used for automatic gain selection for auto-ranging meters, etc.

CHALLENGE: Design a circuit using only two HA-2400s which can be programmed to any of 16 different gains.

Application No. 3

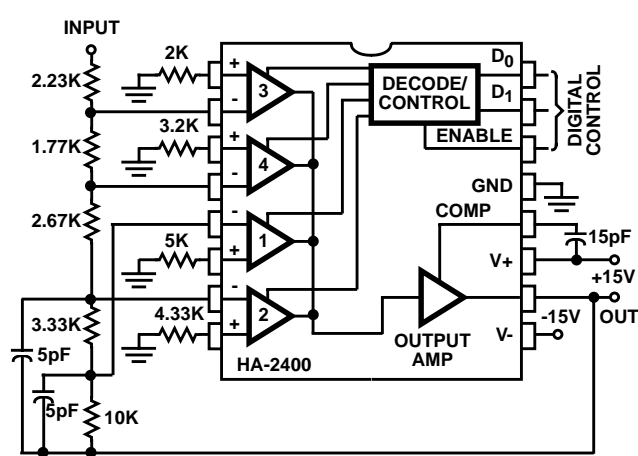


FIGURE 4. AMPLIFIER, INVERTING PROGRAMMABLE GAIN

The circuit above can be programmed for a gain of 0, -1, -2, -4, or -8.

This could also have been accomplished with one input resistor and one feedback resistor per channel in the conventional manner, but this would require eight resistors rather than five.

Application No. 4

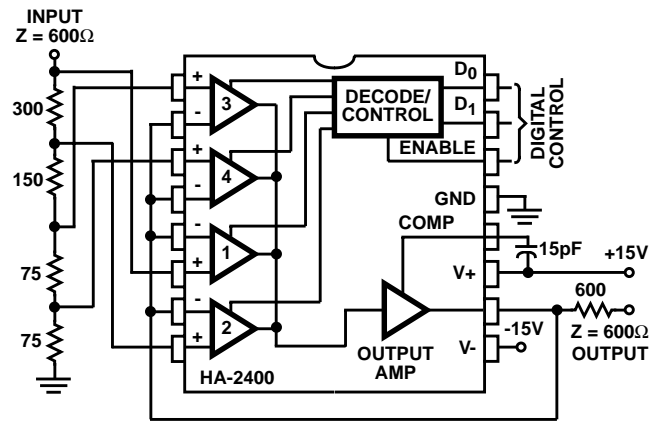


FIGURE 5. PROGRAMMABLE ATTENUATOR

This circuit performs the function of dividing the input signal by a selected constant (1, 2, 4, 8, or ∞ as illustrated). To multiply by a selected constant, see circuit No. 2. While T, π , or L sections could be used in the input attenuator, this is not necessary since the amplifier loading is negligible and a constant input impedance is maintained. The circuit is thus much simpler and more accurate than the usual method of constructing a constant impedance ladder and switching sections in and out with analog switches.

Two identical circuits may be used to attenuate a balanced line.

Application No. 5

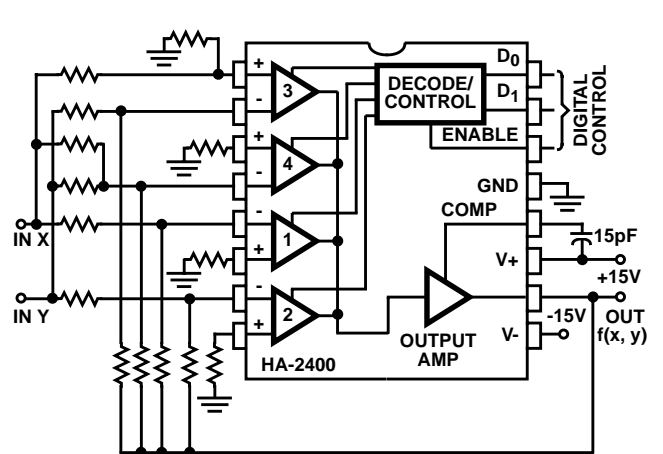


FIGURE 6. ADDER/SUBTRACTOR PROGRAMMABLE FUNCTION

The circuit shown above can be programmed to give the output functions $-K_1X$, $-K_2Y$, $-(K_3X + K_4Y)$, or $K_5X - K_6Y$. Obviously, many other functions of one or more variables can be constructed, including combinations with analog multiplier or logarithmic modules.

This device opens up many new design approaches in digitally controlled analog computation or signal manipulation.

Application No. 6

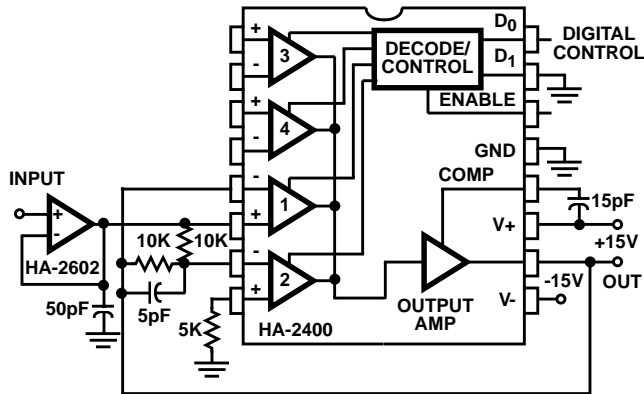


FIGURE 7. PHASE SELECTOR/PHASE DETECTOR/ SYNCHRONOUS RECTIFIER/BALANCED MODULATOR

This circuit passes the input signal at unity gain, either unchanged, or inverted depending on the Digital control input. A buffered input is shown, since low source impedance is essential. Gain can be added by modifications to the feedback networks. Signals up to 100kHz can be handled with 20V_{p-p} output. The circuit becomes a phase detector by driving the Digital Control input with a reference phase at the same frequency as the input signal, the average DC output being proportional to the phase difference, with 0V at +90 degrees. By connecting the output to a comparator, which in turn drives the Digital Control, a synchronous full-wave rectifier is formed.

With a low frequency input signal and a high frequency digital control signal, a balanced (supressed carrier) modulator is formed.

Application No. 7

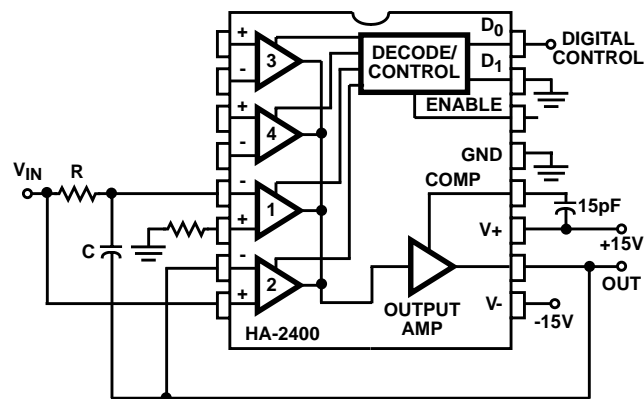


FIGURE 8. INTEGRATOR/RAMP GENERATOR WITH INITIAL CONDITION RESET

It is difficult in practice to set the initial conditions accurately in an integrator. This usually requires wiring contacts of a mechanical relay across the capacitor - leakage currents of solid state switches produce integration inaccuracy. The scheme shown above eliminates these reliability and accuracy problems.

Channel 1 is wired as a conventional integrator, Channel 2 as a voltage follower. When Channel 2 is switched on, the output will follow V_{IN} , and C will discharge to maintain 0V across it. When Channel 1 is then switched on the output will initially be at the instantaneous value of V_{IN} , and then will commence integrating towards the opposite polarity. This circuit is particularly suitable for timing ramp generation using a fixed DC input. Many variations are possible, such as programmable time constant integrators.

Application No. 8

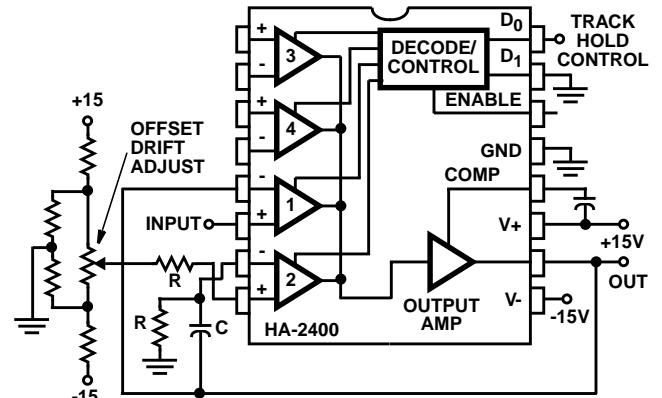


FIGURE 9. TRACK AND HOLD/SAMPLE AND HOLD

Channel 1 is wired as a voltage follower and is turned on during the track/sample time. If the product of $R \times C$ is sufficiently short compared to the period of maximum output frequency, or sample time, C will charge to the output level. Channel 2 is an integrator with zero input signal. When Channel 2 is then turned on, the output will remain at the voltage across C.

Application No. 9

Any oscillator which can be constructed using an op amp, such as the twin-T, phase shift, crystal controlled types, etc. can be made programmable by using the HA-2400. The following illustration is a Wien Bridge type, which is very popular for signal generators, since it is easily tunable over a wide frequency range, and has a very low distortion sine wave output. The frequency determining networks can be designed from about 10Hz to greater than 1MHz. Output level is about $6.0V_{RMS}$. By substituting a programmable attenuator (Circuit No. 4) for the Buffer Amplifier, a very versatile sine wave source for automatic testing, etc. can be constructed.

CHALLENGE: A high Q, narrow band filter can be made by feeding back greater than 1/3 of the output to the negative input. Design a circuit using the HA-2400 and an RC network which can be programmed either to generate or to detect an audio tone of the same frequency. Such a circuit would be quite useful for data communications.

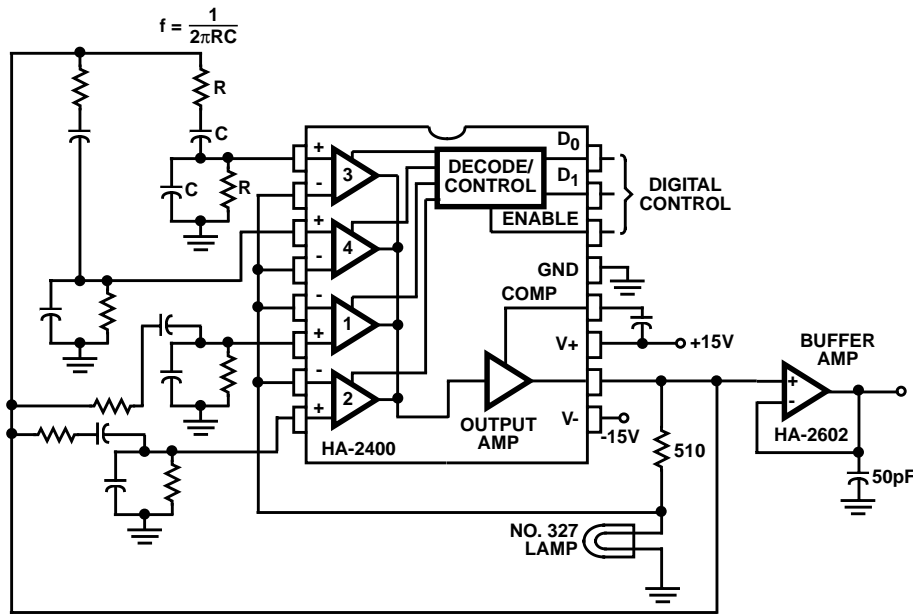


FIGURE 10. SINE WAVE OSCILLATOR PROGRAMMABLE FREQUENCY

An even simpler circuit can be made by wiring one channel as an amplifier, choosing the compensation capacitor to yield the minimum required bandwidth or slew rate. When the Enable input is pulled low, the output will tend to remain at its last level, because of the charge remaining on the compensating capacitor.

Application No. 10

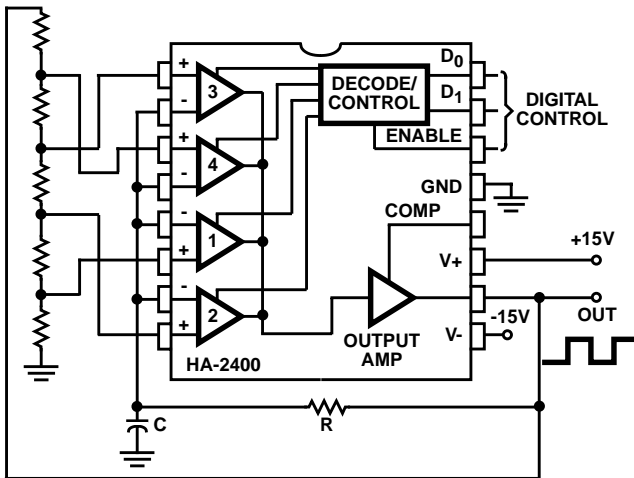


FIGURE 11. MULTIVIBRATOR, FREE RUNNING, PROGRAMMABLE FREQUENCY

This is the simplest of any programmable oscillator circuit, since only one stable timing capacitor is required. The output square wave is about 25V_{P-P} and has rise and fall times of about 0.5μs. If a programmable attenuator circuit (No. 4) is placed between the output and the divider network, 16 frequencies can be produced with two HA-2400s and still only one timing capacitor.

A precision programmable square-triangle generator can also be constructed by adapting circuit described in Intersil Application Note AN507 to the HA-2400.

Application No. 11

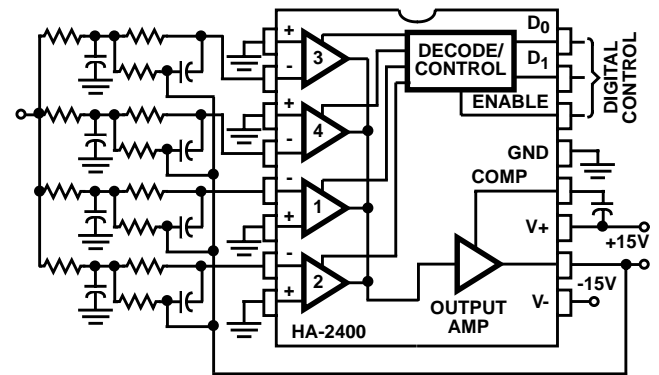


FIGURE 12. PROGRAMMABLE ACTIVE FILTER

Shown above is a second order low pass filter with programmable cutoff frequency. This circuit should be driven from a low source impedance since there are paths from the output to the input through the unselected networks.

Virtually any filter function which can be constructed with a conventional op amp can be made programmable with the HA-2400.

A useful variation would be to wire one channel as a unity gain amplifier, so that one could select the unfiltered signal, or the same signal filtered in various manners. These could be cascaded to provide a wide variety of programmable filter functions.

Application No. 12

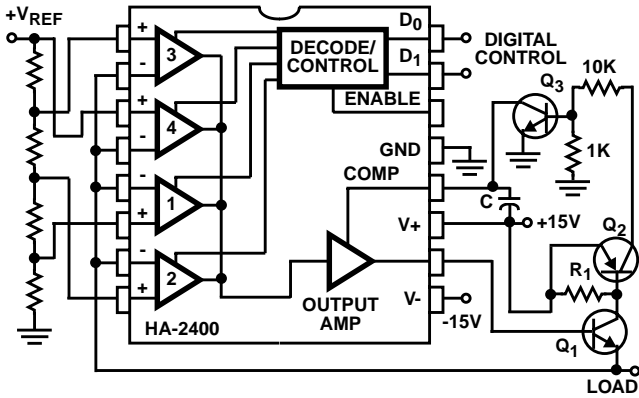


FIGURE 13. POWER SUPPLY PROGRAMMABLE

Many systems require one or more relatively low current voltage sources which can be programmed to a few predetermined levels. It is no longer necessary to purchase a programmable power supply with far more capability than needed. The circuit shown above produces positive output levels, but could be modified for negative or bipolar outputs. Q₁ is the series regulator transistor, selected for the required current and power capability. R₁, Q₂ and Q₃ form an optional short circuit protection circuit, with R₁ chosen to drop about 0.7V at the maximum output current. The compensation capacitor, C, should be chosen to keep the overshoot, when switching, to an acceptable level.

CHALLENGE: Design a supply using only two HA-2400s which can be programmed to 16 binary weighted (or 10 BCD weighted) output levels.

Application No. 13

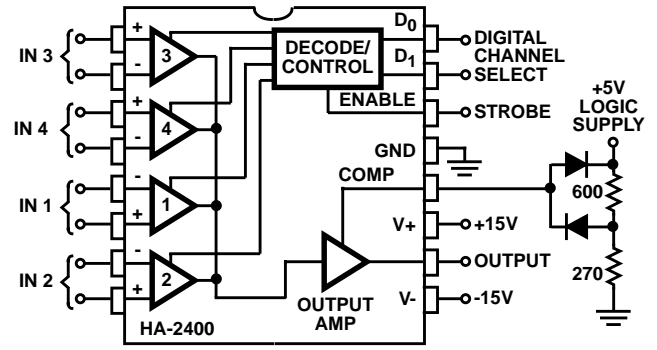


FIGURE 14. COMPARATOR, FOUR CHANNEL

Application No. 14

When operated open loop without compensation, the HA-2400 becomes a comparator with four selectable input channels. The clamping network at the compensation pin limits the output voltage to allow DTL or TTL digital circuits to be driven with a fanout of up to ten loads.

Output rise and fall times will be about 100ns for differential input signals of several hundred millivolts, but will be in the microsecond region for small differential signals.

The circuit can be used to compare several signals against each other or against fixed references; or a single signal can be compared against several references. A "window comparator", which assures that a signal is within a voltage range, can be formed by monitoring the output polarity while rapidly switching between two channels with different reference inputs and the same signal input.

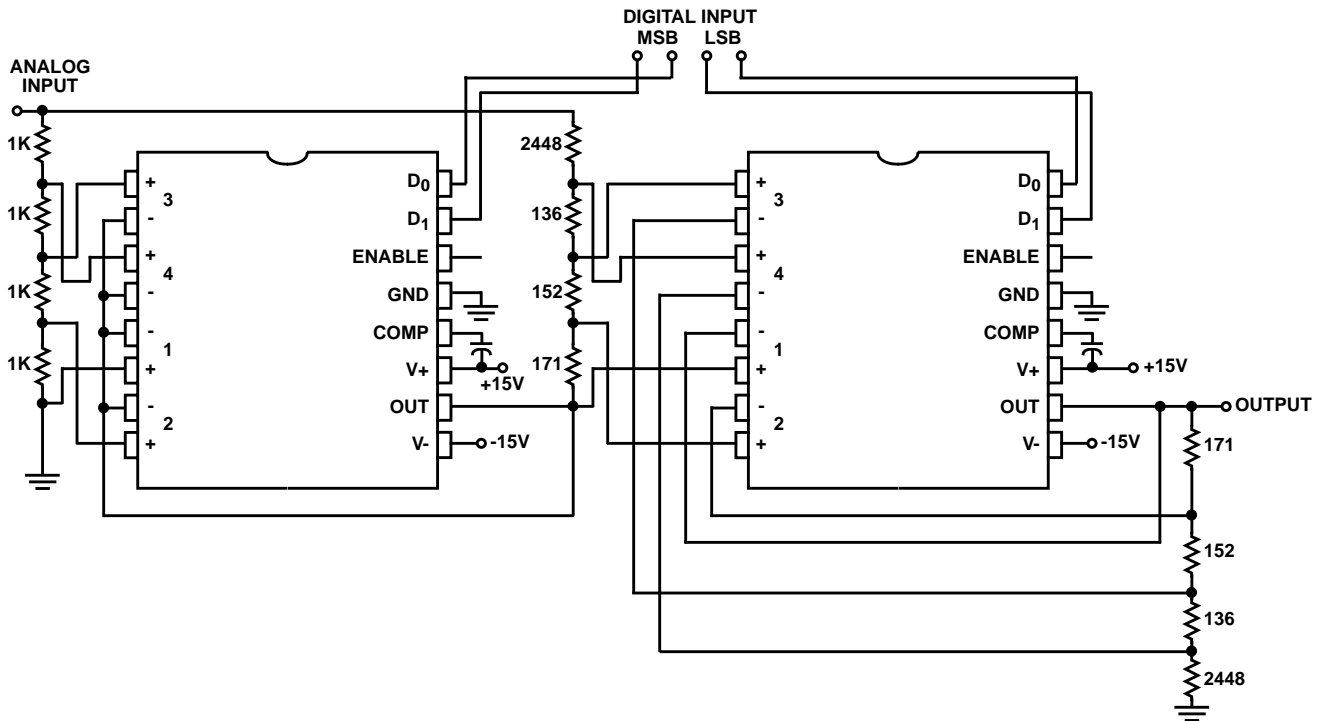


FIGURE 15. MULTIPLYING D TO A CONVERTER

Application Note 514

The circuit above performs the function,

$$V_{OUT} = V_{IN} \times \frac{N}{16},$$

where N is the binary number from 0 to 15 formed by the digital input. If the analog input is a fixed DC reference, the circuit is conventional 4-bit D to A. The input could also be a variable or AC signal, in which case the output is the product of the analog signal and the digital signal.

The circuit on the left is a programmable attenuator with weights of 0, 1/4, 1/2, or 3/4. The circuit on the right is a noninverting adder which adds weights to the first output of 0, 1/6, 1/8 or 3/16.

If four quadrant multiplication is required, place the Phase Selector circuit (No. 6) in series with either the analog input or output. The D₀ input of that stage becomes the + or - sign bit of the digital input.

More Challenges

One of our favorite college textbooks paused at each climactic point with a statement to the effect that, "Proof of the following theorem is omitted and is suggested as an exercise for the student."

The following is the list of some additional applications in which we believe the HA-2400 will prove very valuable. The "proofs", at present, remain as exercises for our ingenious readers.

- A to D Converter, Dual Slope Integrating
- Active Filter, State Variable Type with Programmable Frequency and/or Programmable "Q"
- Amplifier with Programmable DC Level Shift

- Chopper Amplifiers
- Crossbar Switches
- Current Source, Programmable
- FM Stereo Modulator
- F.S.K. Modem
- Function Generators, Programmable
- Gyrator, Programmable
- Monostable Multivibrator, Programmable
- Multiplier, Pulse Averaging
- Peak Detector with Reset
- Resistance Bridge Amplifier/Comparator with Programmable Range
- Sense Amp/Line Receiver with Programmable Threshold
- Spectrum Analyzer, Scanning Type
- Sweep Generator, Programmable
- Switching Regulator
- Touch-Tone™ Generator/Detector (Use Intersil HD-0165 Keyboard Encoder IC)

Feedback

We believe we have only scratched the surface of possible applications for a multiple channel operational amplifier.

If you have a solution for any of the previous "challenges" or any new application, please let us know. Anything from a one word description to a tested design will be welcome.

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