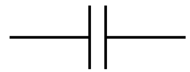
MAS836 – Sensor Technologies for Interactive Environments

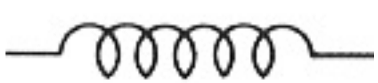
Lecture 2 – Analog Conditioning Electronics, Pt. 2

Reading…

- Horowitz and Hill
  - Finish Chapter 1, read Chapters 4&5
- Fraden
  - Interface Electronic Circuits Chapter (Chapter 6 of last edition)

Reactive Impedance

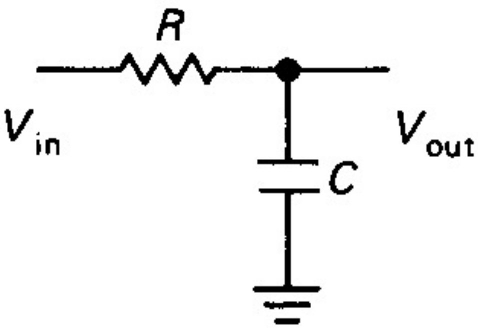
- The Capacitor 
  - Adds in parallel like resistors add in series
  - Reciprocal-adds in series like resistors add in parallel
- Impedance of capacitor = $-j/\omega C = -j/(2\pi fC)$ *C in Farads*
  - Pass AC, block DC
    - Capacitor current: $I_c = C\, dV/dt$
- Impedance of inductor = $j\omega L = j(2\pi fL)$ *L in Henries*
  - Block AC, pass DC
    - Inductor Voltage: $V = L\, dI/dt$



Passive RC Filters

- Passive LP Filter: RC network: $f_c = 1/(2\pi RC)$

-3dB = 0.707



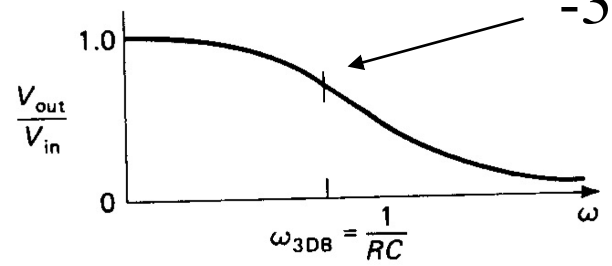
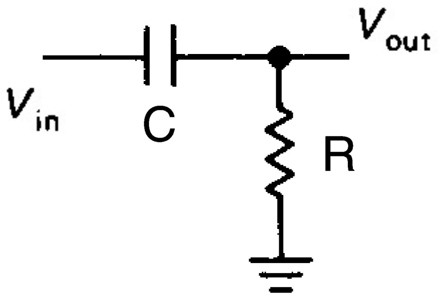


Figure 1.59. Frequency response of low-pass filter.

- Passive HP filter: RC network: $f_c = 1/(2\pi RC)$



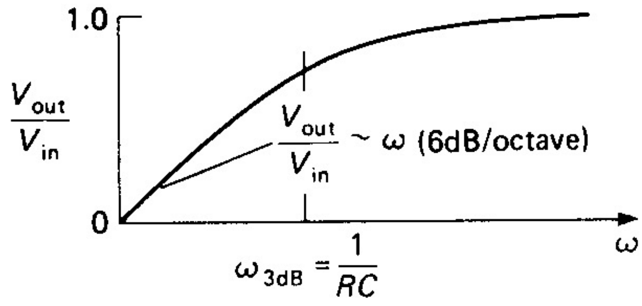


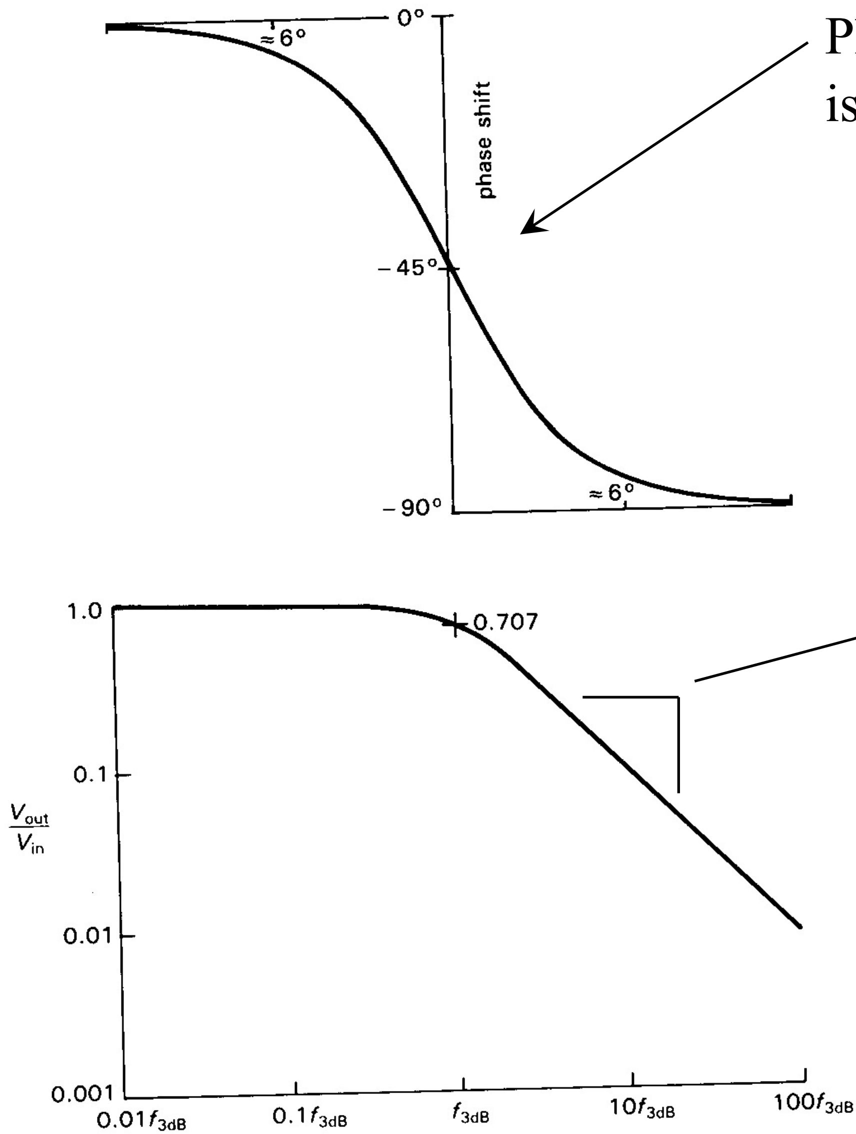
Figure 1.55. Frequency response of high-pass filter.

Note - To take the magnitude of a complex impedance, add the real and imaginary parts in *quadrature*

L/C Reciprocal Action

- If a capacitor is replaced with an inductor, the filter flips its nature
  - A capacitive highpass becomes an inductive lowpass

Passive RC Filter Rolloff



Phase between input and output is 45° at cutoff

Bode Plot:
Freq. Response as a log-log plot

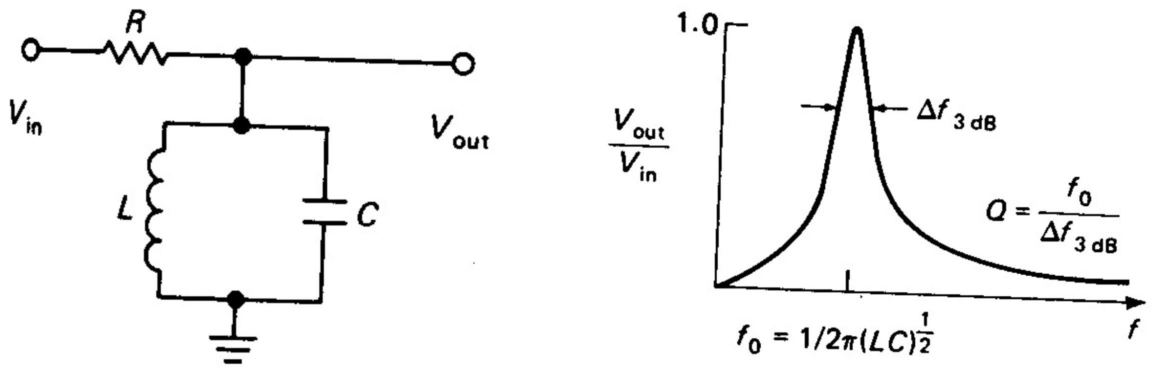
Rolloff is 6 dB per Octave (2x)
20 dB per Decade (10x)

Figure 1.60. Frequency response (phase and amplitude) of low-pass filter, plotted on logarithmic axes. Note that the phase shift is 45° at the 3dB point and is within 6° of its asymptotic value for a decade of frequency change.

Passive RLC Filters

- Resonant parallel RLC bandpass filters

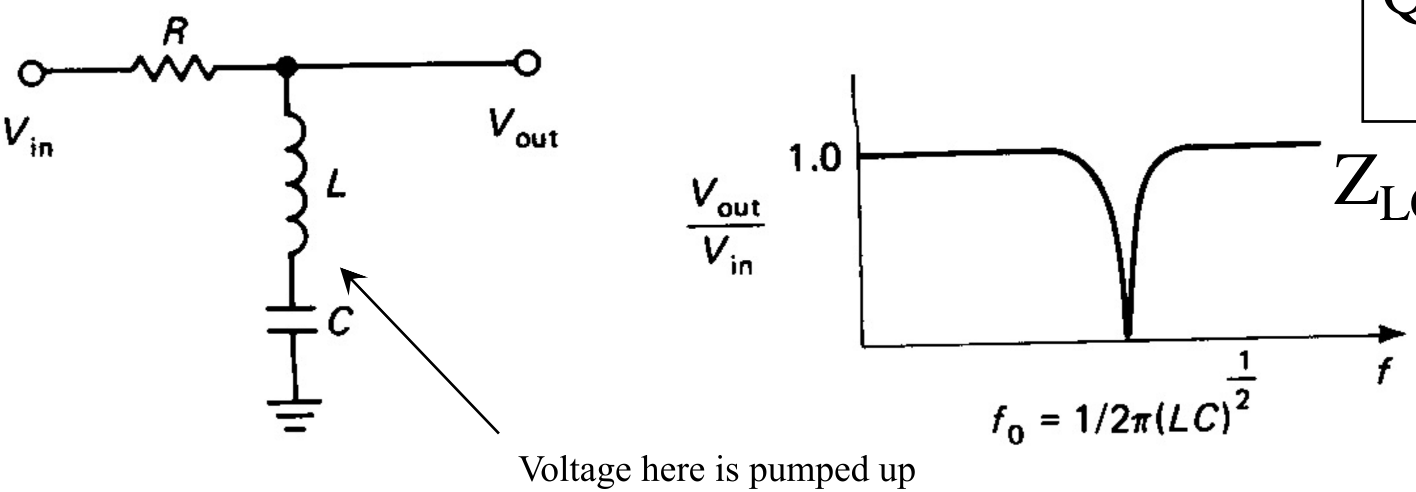
$$Q = \omega_0 RC = f_0/\Delta f_{3dB}$$



$$Z_{LC} \rightarrow \infty \;@\; f_0$$

- Resonant series RLC notch filters

$$Q = \omega_0 (L/R) = f_0/\Delta f_{3dB}$$



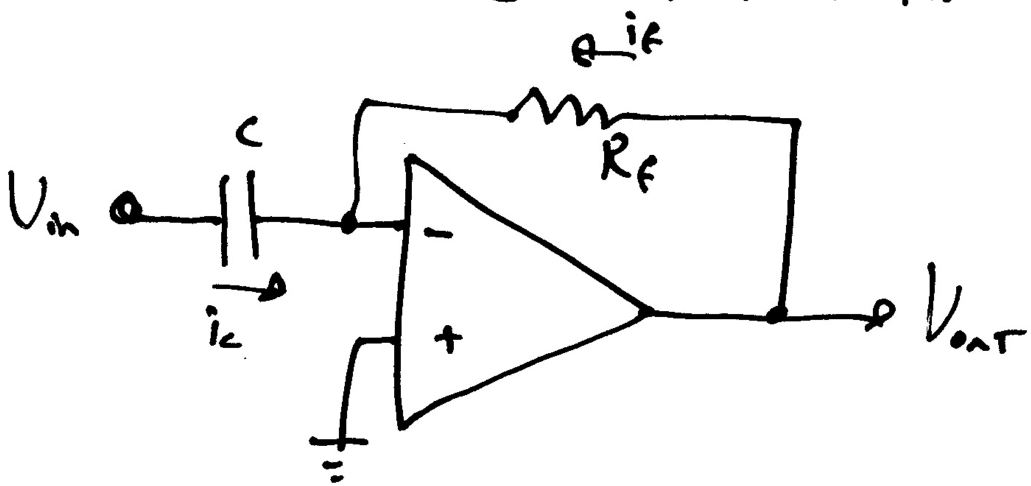
$$Z_{LC} \rightarrow 0 \;@\; f_0$$

Active Filters

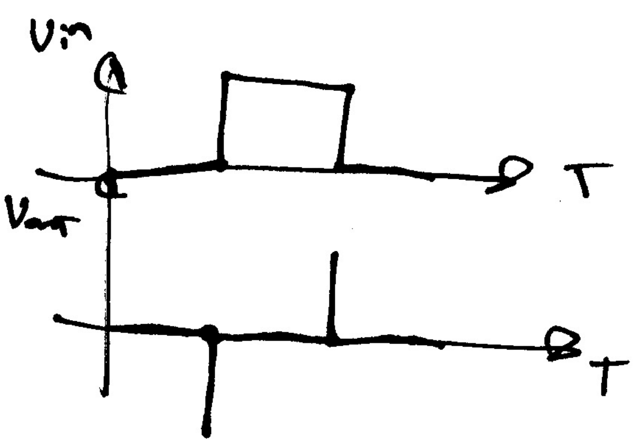
- The Differentiator
- The Active High-Pass Filter
- Principle of Feedback Inversion
- The Integrator
- The Leaky Integrator (LP filter)
- Buffered Passive Second-Order Filter
- Sallen-Key (or VCVS) LP, HP, BP filters
- Single-OpAmp VCVS BP filter

The Differentiator

The Differentiator



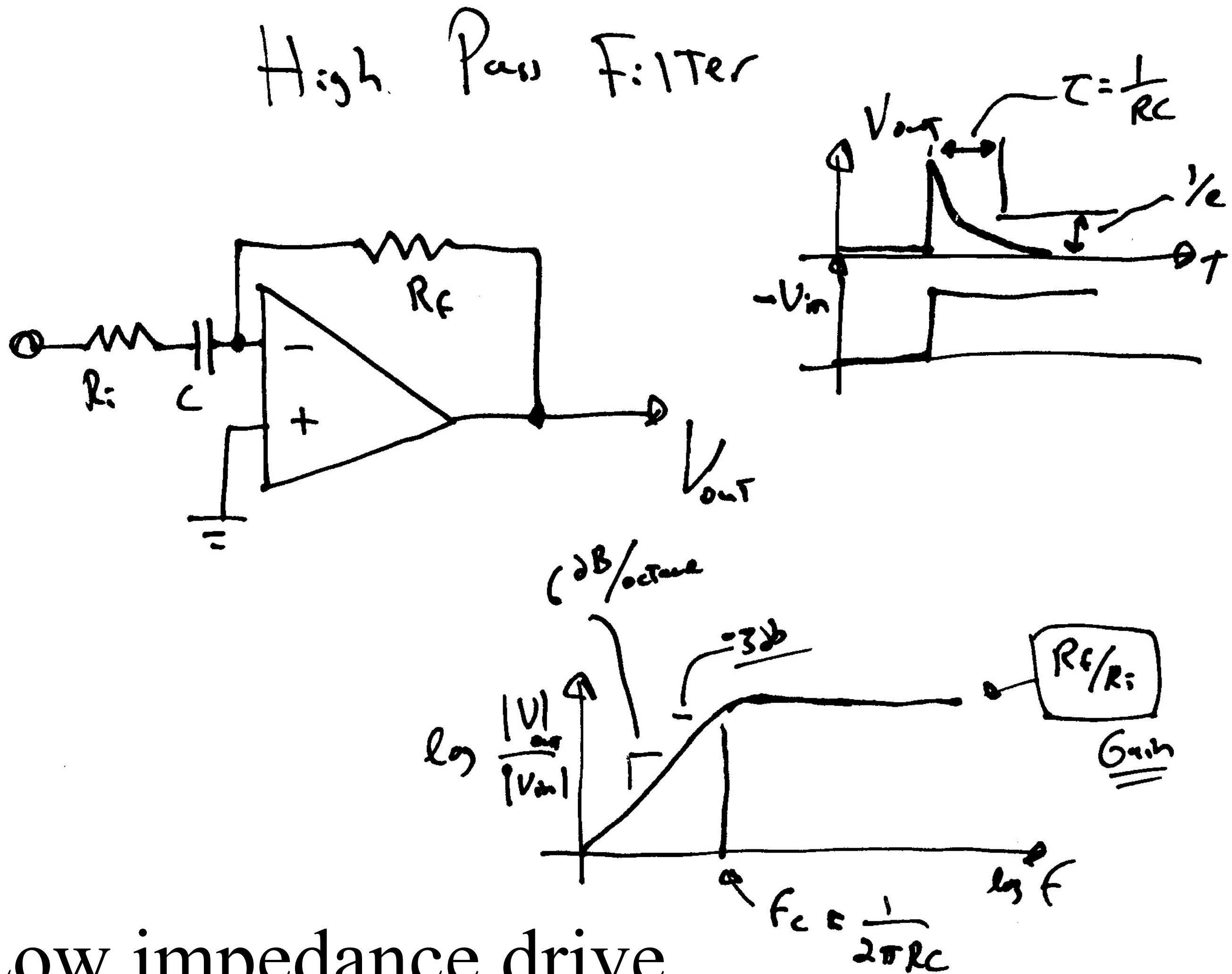
$$i_f = -i_c$$



$$\frac{V_{out}}{R_f} = -C\,\frac{dV_{in}}{dT}$$

$$\boxed{V_{out} = -R_f C\,\frac{dV_{in}}{dT}}$$

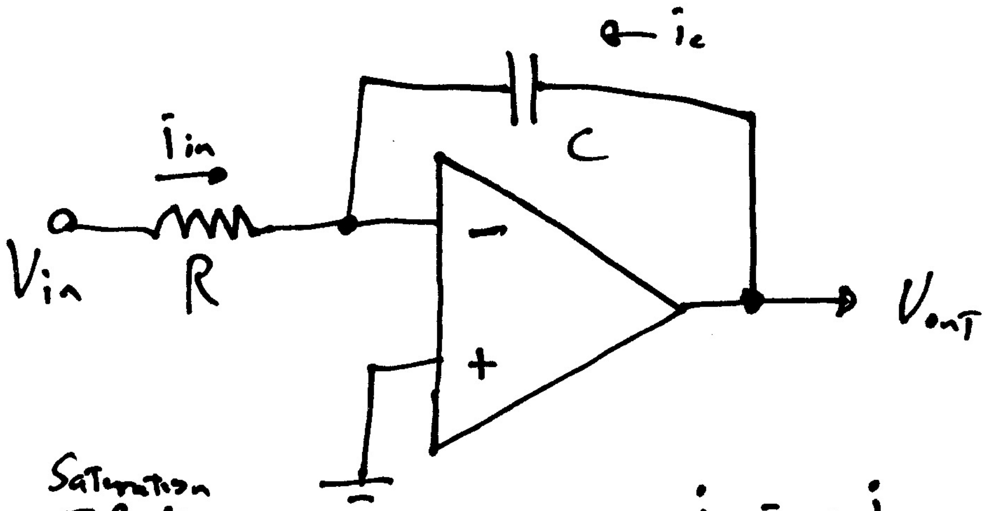
The First-Order Active High Pass Filter



- Low impedance drive
- Voltage gain via R_f/R_i

The Integrator

The Integrator

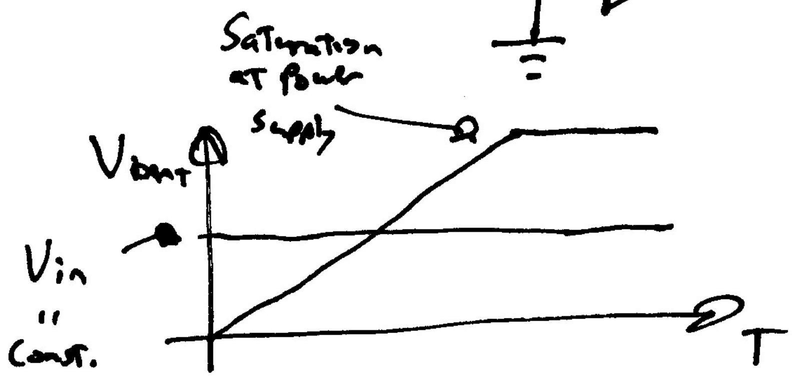


$$Z_c = \frac{1}{j\omega C}$$

$$i_c = C \frac{dV}{dT}$$

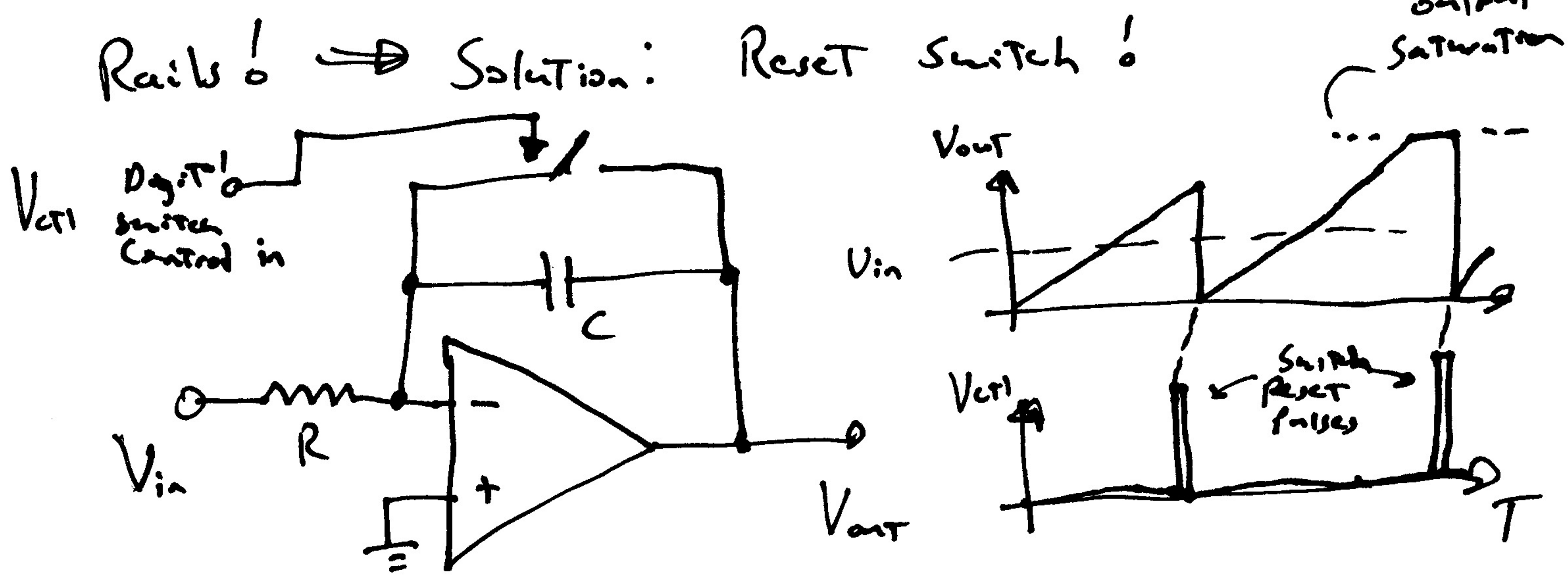
$$i_c = -i_{in} \Rightarrow C\frac{dV_{out}}{dT} = -\frac{V_{in}}{R}$$

$$\frac{dV_{out}}{dT} = -\frac{V_{in}}{RC} \Rightarrow V_{out} = \frac{-1}{RC}\int V_{in}\,dt$$



Saturates at rail!!

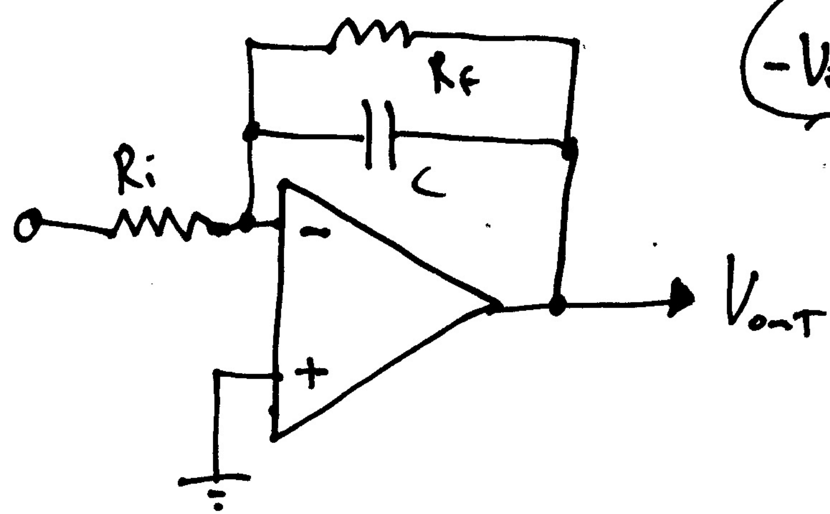
Integrator with Reset Switch

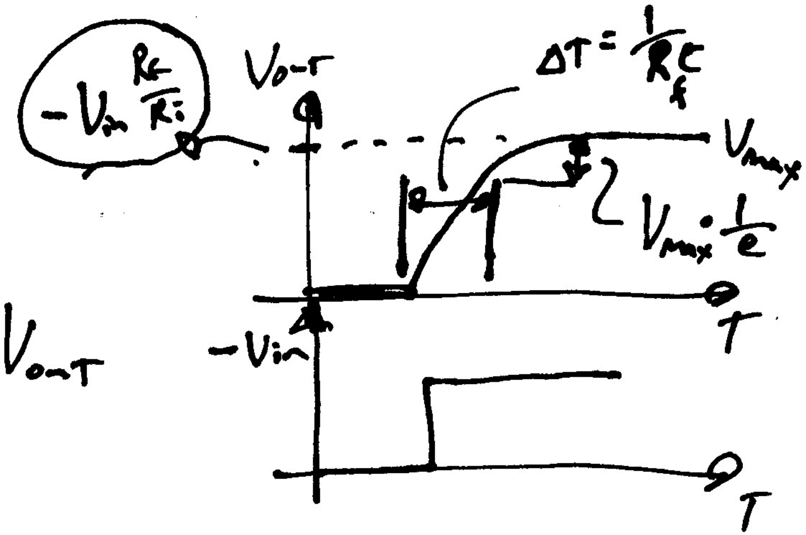


- Electronic switch in feedback forces output to ground when closed
  - Discharges capacitor
    - Resets Integrator!

The First-Order Active Low Pass Filter

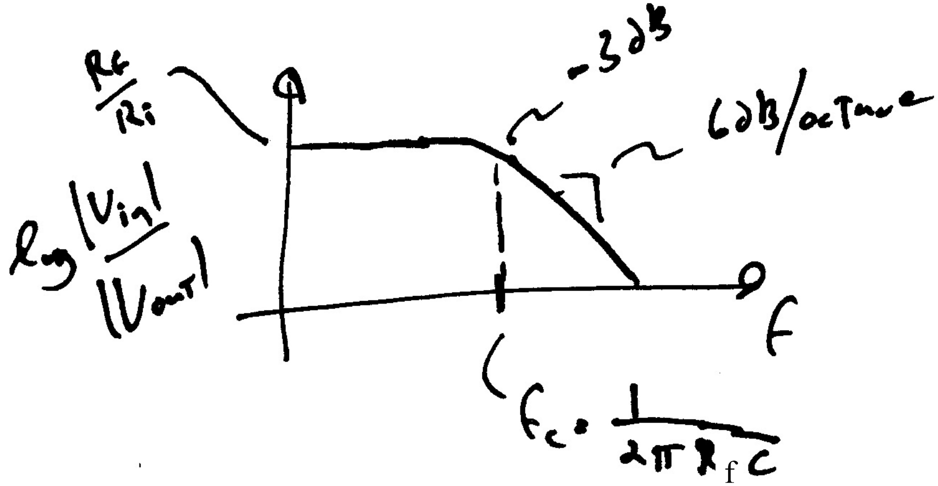
The Leaky Integrator ⟹ Low Pass Filter



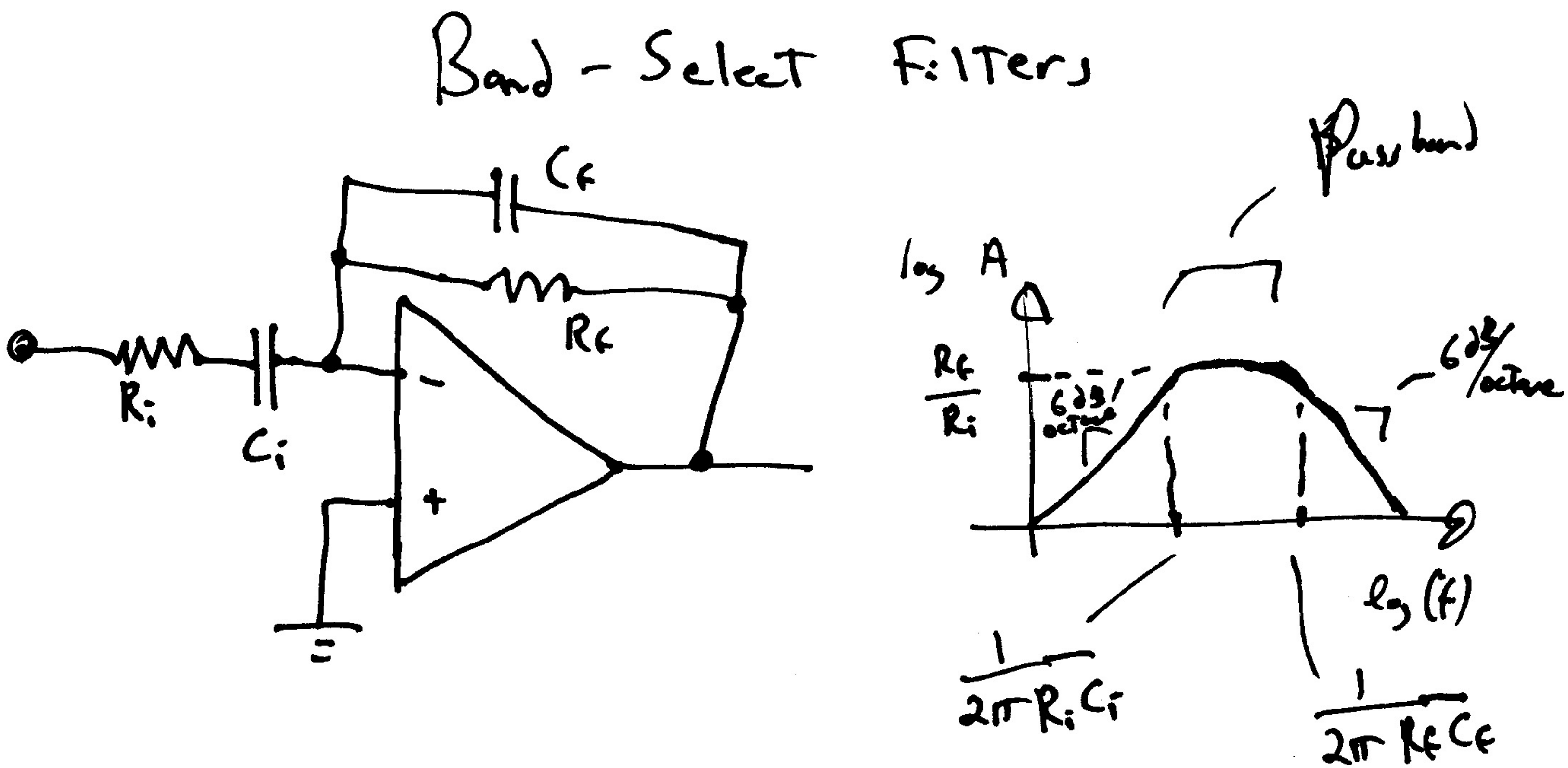


Low impedance output!!

Voltage gain!!



The Band-Select Filter



- Cascaded high and low pass filters
  - Always follow high-pass with low-pass (noise)
    - Low-Pass cutoff needs to be below high-pass cutoff!
  - No Q, first-order rolloffs

Sallen-Key Filters – Ref. Active Filter Cookbook

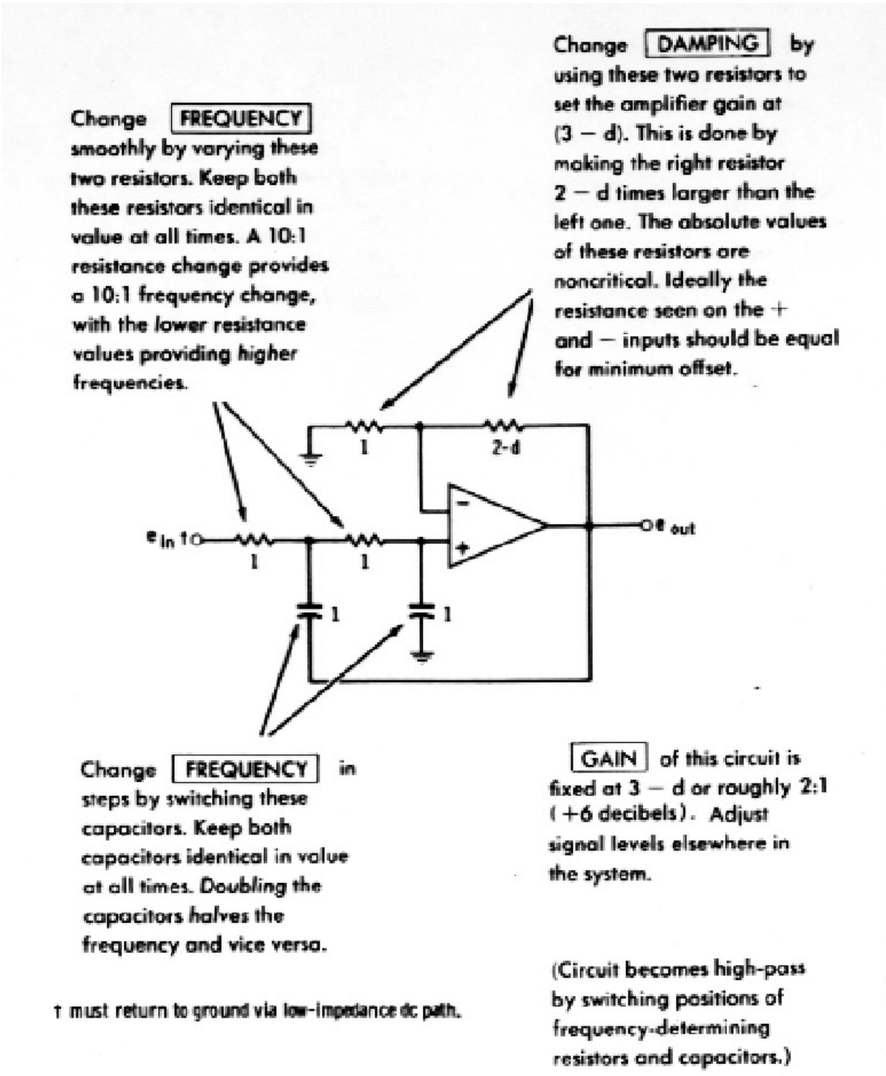


Fig. 6-8. Adjusting or tuning the equal-component-value, Sallen-Key, second-order, low-pass section.

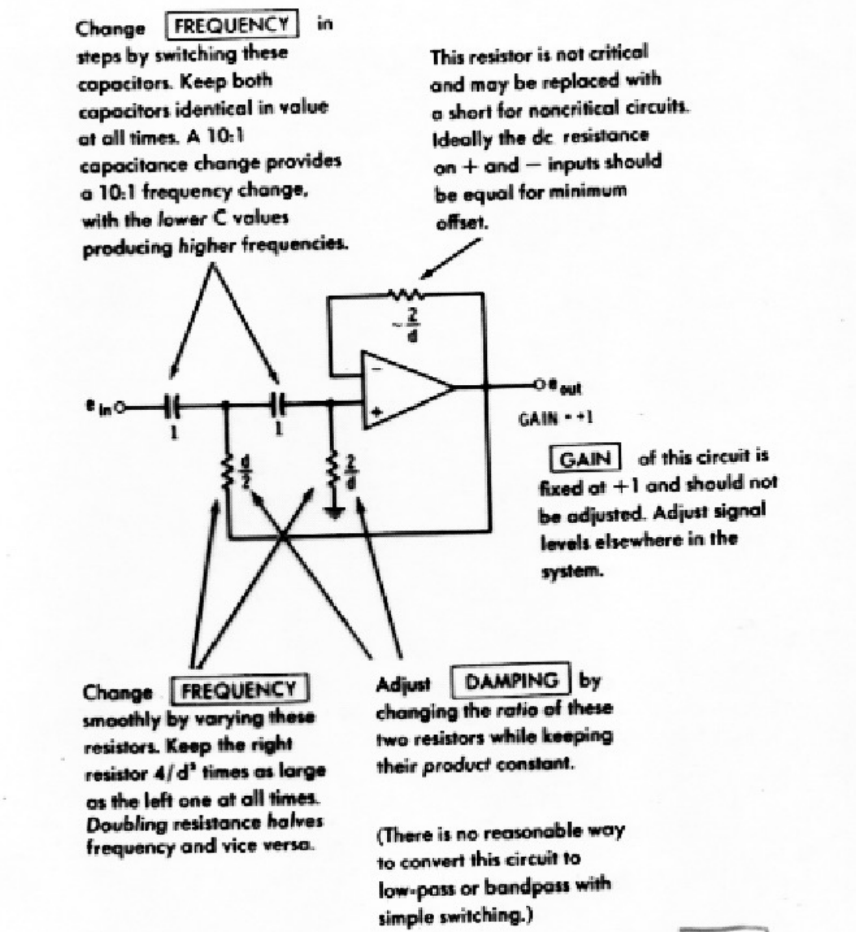


Fig. 8-5. Adjusting or tuning the unity-gain, Sallen-Key, second-order high-pass section.

VCVS Filters

Multiple Feedback Bandpass

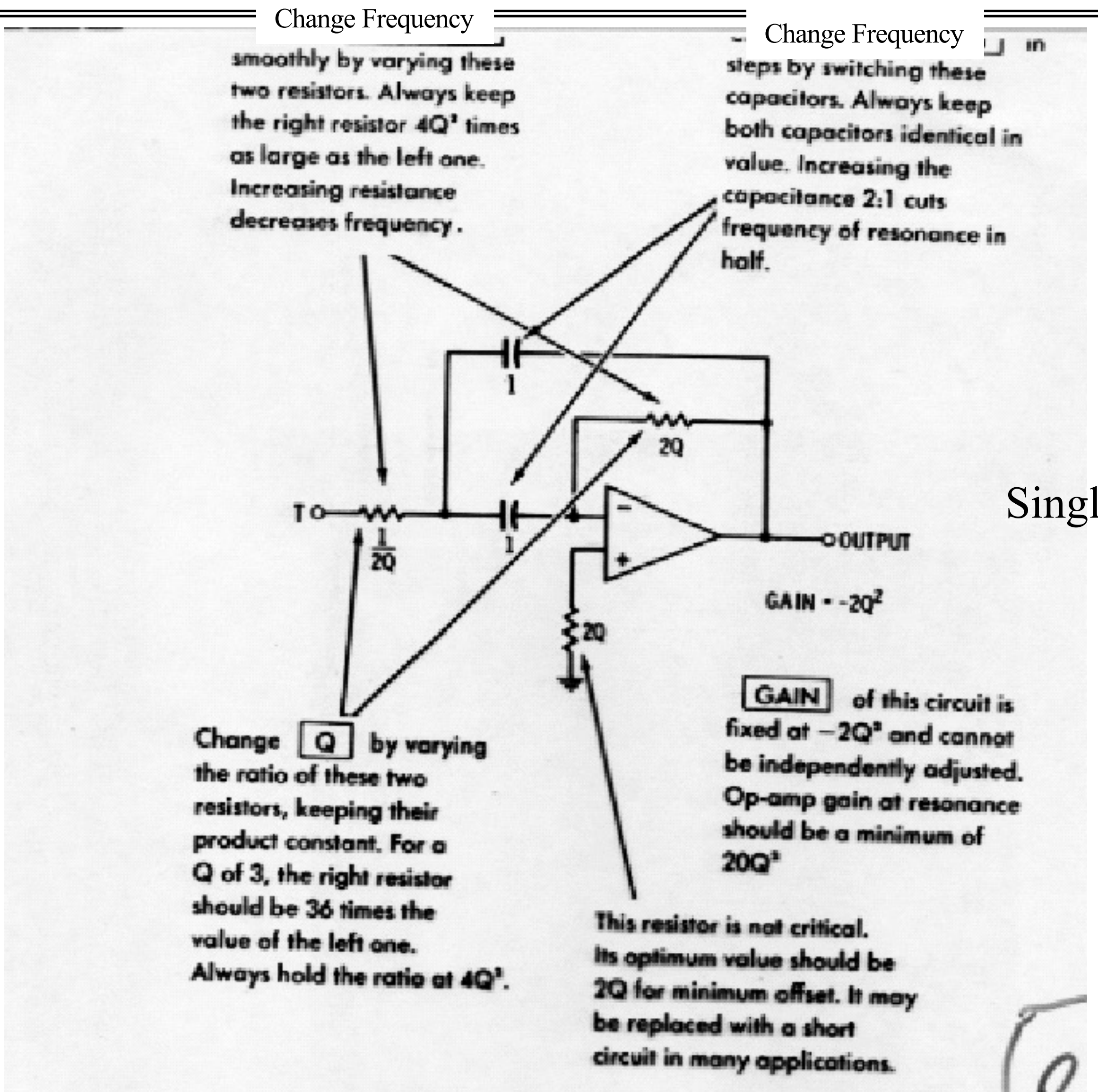


Fig. 7-4. Tuning the single-amplifier, multiple-feedback circuit.

Single-OpAmp VCVS BP filter

Good for Q up to 10 or so

Fr. Active Filter Cookbook

Low Pass Filter Responses

Best-Time-Delay Filter—Sometimes called a *Bessel* filter. This one has the best possible time delay and overshoot response, but it has a droopy passband and very gradual initial falloff.

Compromise Filter—Often called a *Paynter* or *transitional Thompson-Butterworth* filter. It has a somewhat flatter passband and initially falls off moderately faster than the best-time-delay filter, with only moderately poorer overshoot characteristics.

Flattest-Amplitude Filter—This is the *Butterworth* filter and has the flattest passband you can possibly provide combined with a moderately fast initial falloff and reasonable overshoot. The overshoot characteristics appear in Fig. 4-10. *The Butterworth is often the best overall filter choice.* It also has a characteristic that sets all cascaded sections to the same frequency, which makes voltage control and other wide-range tuning somewhat easier.

Slight-Dips Filter—This is the first of the *Chebyshev filters.* It has a slight peaking or ripple in the passband, a fast initial falloff, and a transient response only slightly worse than the flattest-amplitude filter. The ripple depends on the order and varies from 0.3 dB for the second-order response down to .01 dB at the sixth-order.

One-dB-Dips Filter—This is another Chebyshev filter. It has 1 dB of passband ripple. The ripple peaks and troughs are constant in amplitude, but you get more of them as the order increases. They tend to crowd together near the cutoff frequency, particularly when viewed on a log response plot.

Two-dB-Dips Filter—Another Chebyshev filter. The 2-dB ripple gives faster initial stopband falloff and progressively poorer transient and overshoot characteristics.

Three-dB-Dips Filter—This final Chebyshev filter offers the fastest initial falloff you can possibly get in a filter with acceptable passband lumps and continually increasing attenuation in the stopband.

Response set by adjusting R's and C's

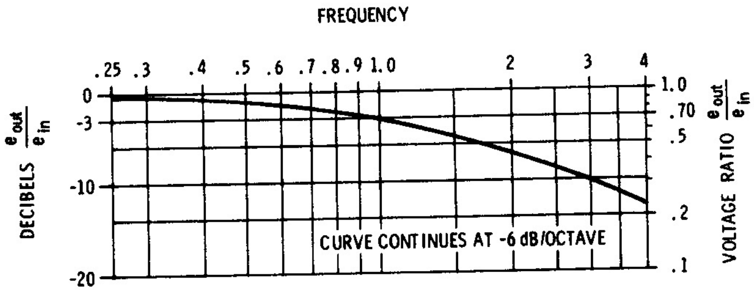
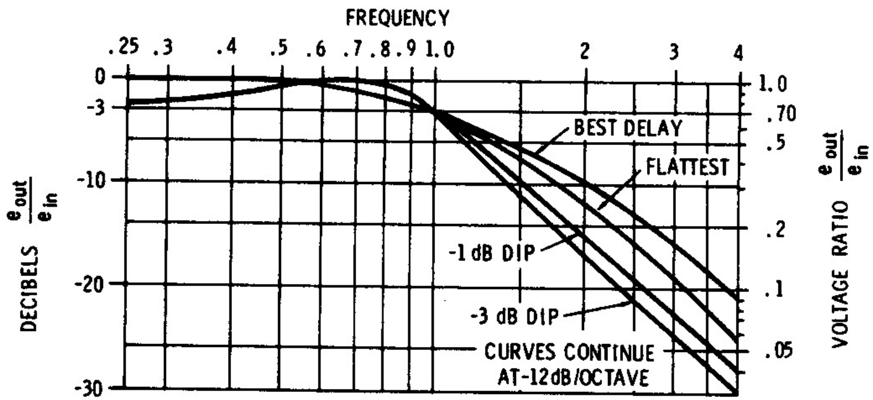


Fig. 4-4. First-order low-pass response.



(A) Response curves.

A second-order filter is built with a single second-order section. Its ultimate attention rate is —12 dB/octave.

For a cutoff (—3 dB) frequency of f, the section parameters are:

Filter Type	Second-Order Section	
	Frequency	Damping
Best Delay	1.274 f	1.732
Compromise	1.128 f	1.564
Flattest Amp	1.000 f	1.414
Slight Dip	0.929 f	1.216
1-Decibel Dip	0.863 f	1.045
2-Decibel Dip	0.852 f	0.895
3-Decibel Dip	0.841 f	0.767

Zero frequency attenuation is 0 decibels for first four filter types, —1 dB for 1-dB dip, —2 dB for 2-dB dip, and —3 dB for 3-dB dip filter types.

NOTE—Values on this chart valid *only* for second-order filters. See other charts for suitable values when sections are cascaded.

Or just run an applet…

- Analog Devices, TI, etc.

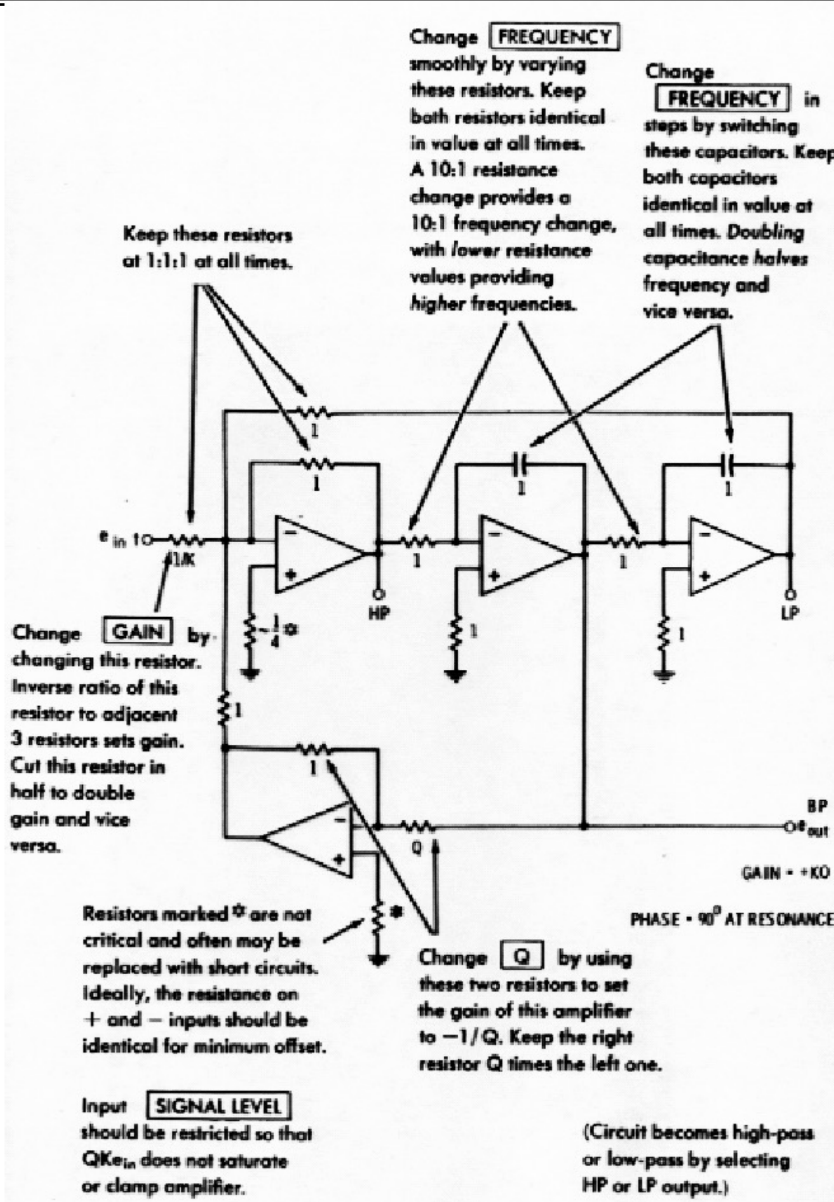
http://www.analog.com/designtools/en/filterwizard/

http://webench.ti.com/webench5/power/webench5.cgi?app=filterarchitect&filterType=Lowpass

Most relevant to class:

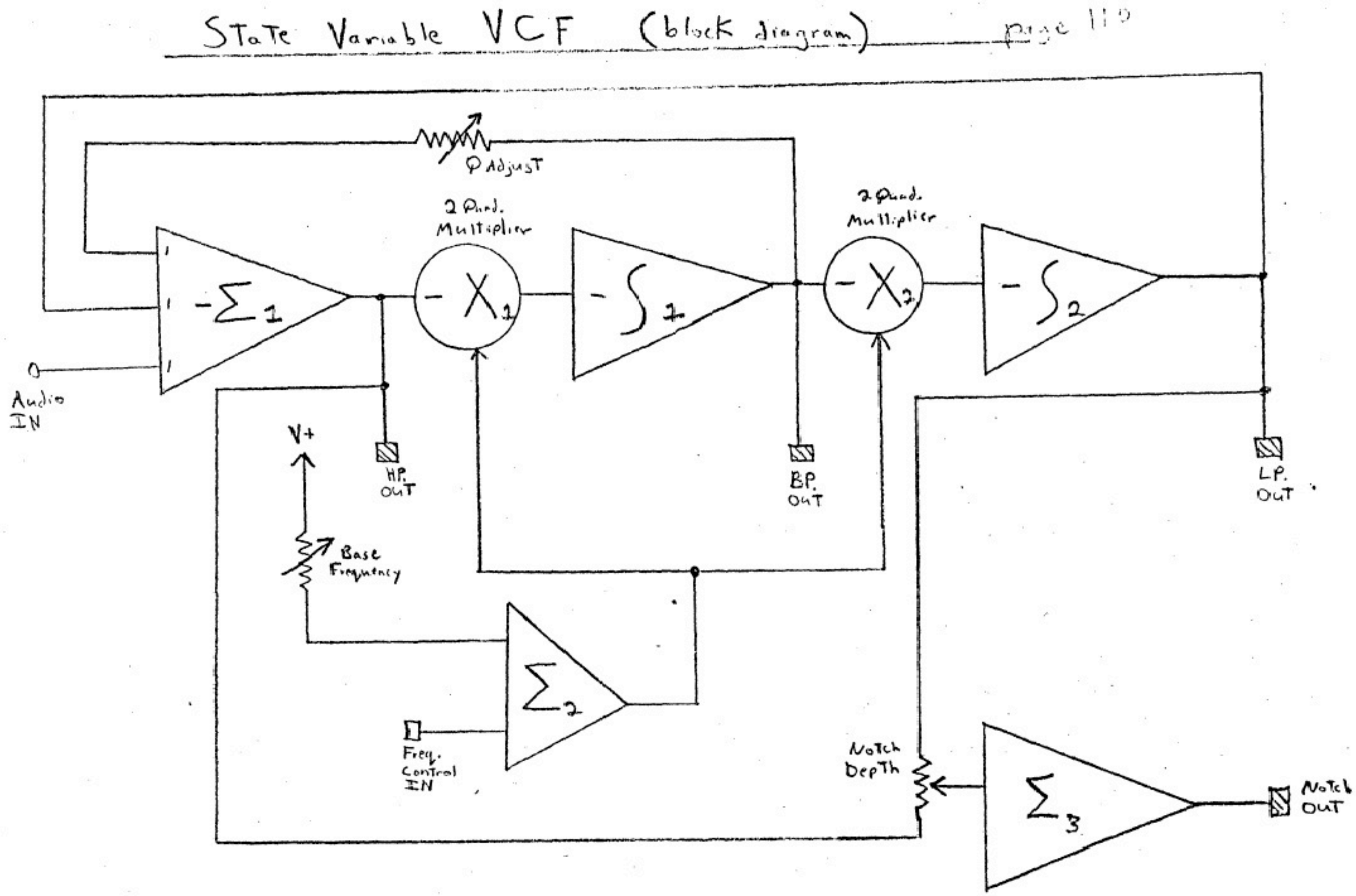
http://sim.okawa-denshi.jp/en/Fkeisan.htm

State Variable Filter



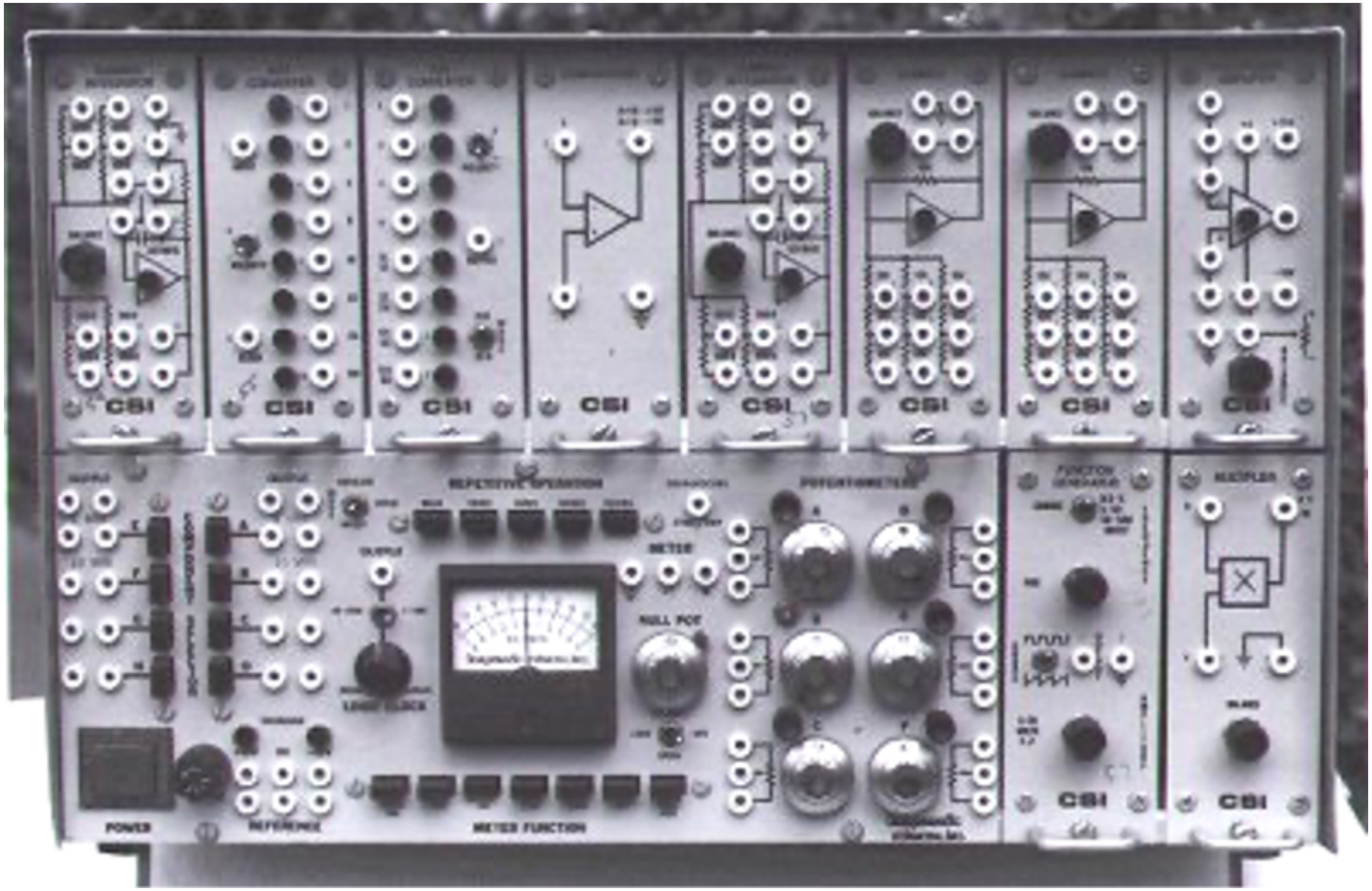
- Very high Q possible (e.g., 500!)
- Simultaneous outputs
- Other varieties (BiQuad, etc.)
- Can make frequency-tunable w. multipliers substituted for coupling resistors
  - (VCF)
- Switched-Capacitor Filter Intro.

The State Variable Filter



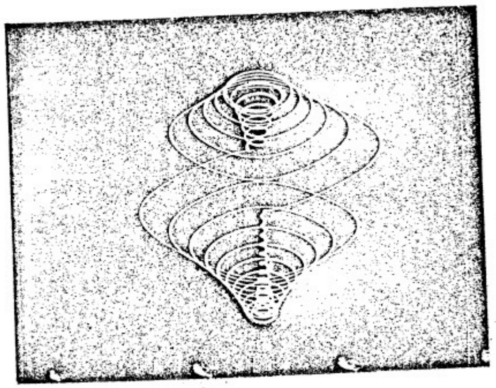
- Analog Computer set up to solve a general Second-Order Differential Equation
  - Exhibits rolloff, damping, and resonance
  - Simultaneous low-pass, bandpass, high-pass, and notch outputs available

Modulars are Analog Computers?

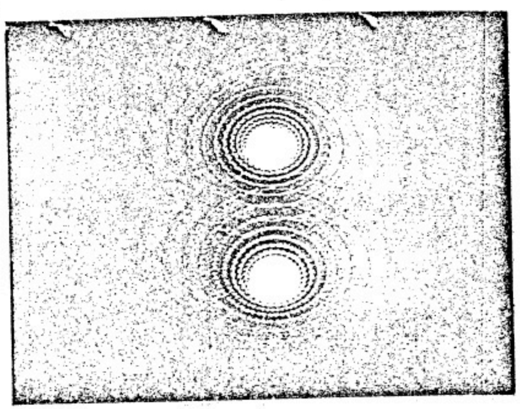


Compumedic Analog Computer from 1971

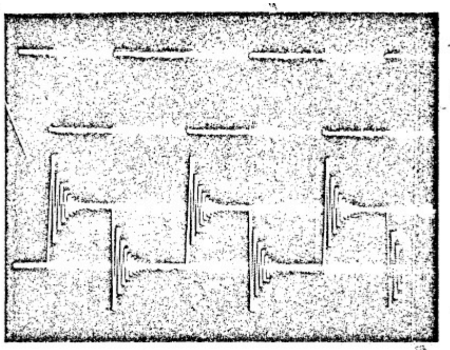
State Variable Signals



Photo#40 - Crossplot of bandpass vs. lowpass outputs for a square/sine/triangle mix at the audio input



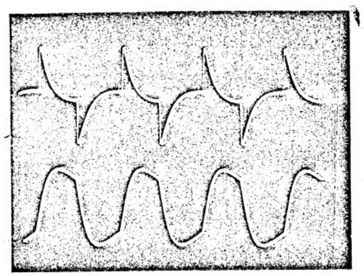
Photo#41 - crossplot of Bandpass vs. Lowpass outputs for a square wave audio input and a high frequency pulse added to the control input



Square wave audio input to VCF

Output of Low-pass with resonance added

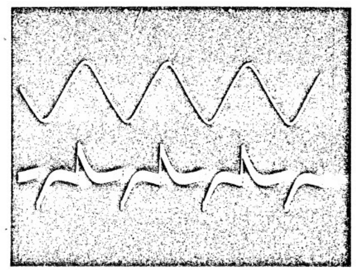
Photo#36 - Ring oscillation with resonance



High Pass output

Low Pass

Filter waveforms without resonance
(input is still a square wave)
Photo#38



Bandpass

Notch output

Photo#39 - Filter waveforms without resonance
(Square wave input)

Limitations on Filter Performance

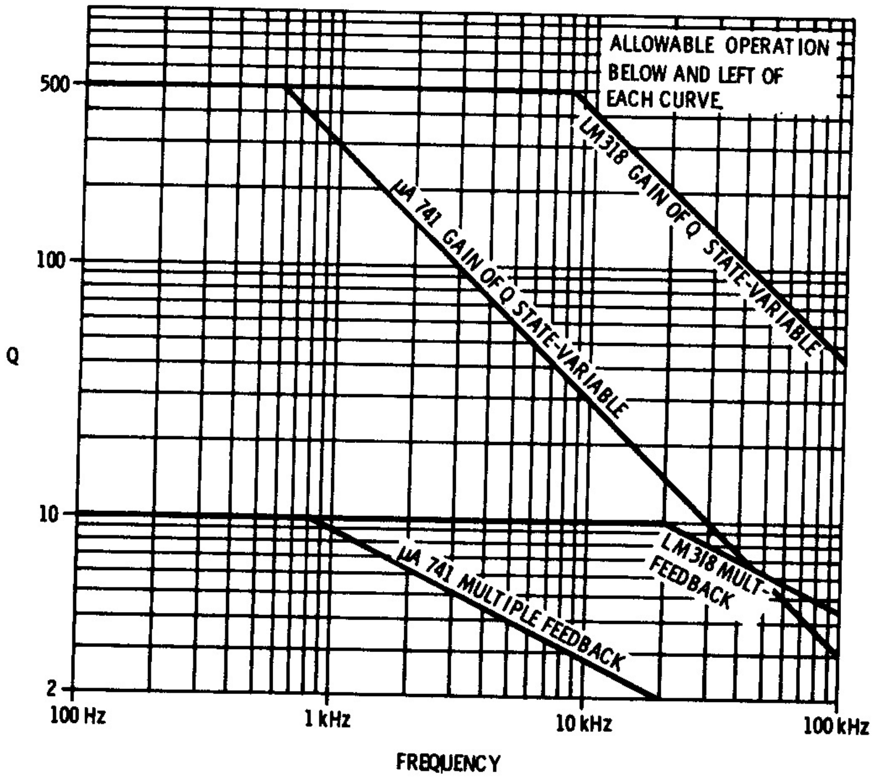


Fig. 7-14. Q and frequency limits for active bandpass filters, small output swings.

- The choice of OpAmp affects how well a given filter will perform
  - Multiple-OpAmp filters can attain higher Q's than single-OpAmp filters
  - Faster OpAmp's work better too
    - Accumulated Phase Shifts can cause oscillation!

Voltage-Controlled Filter

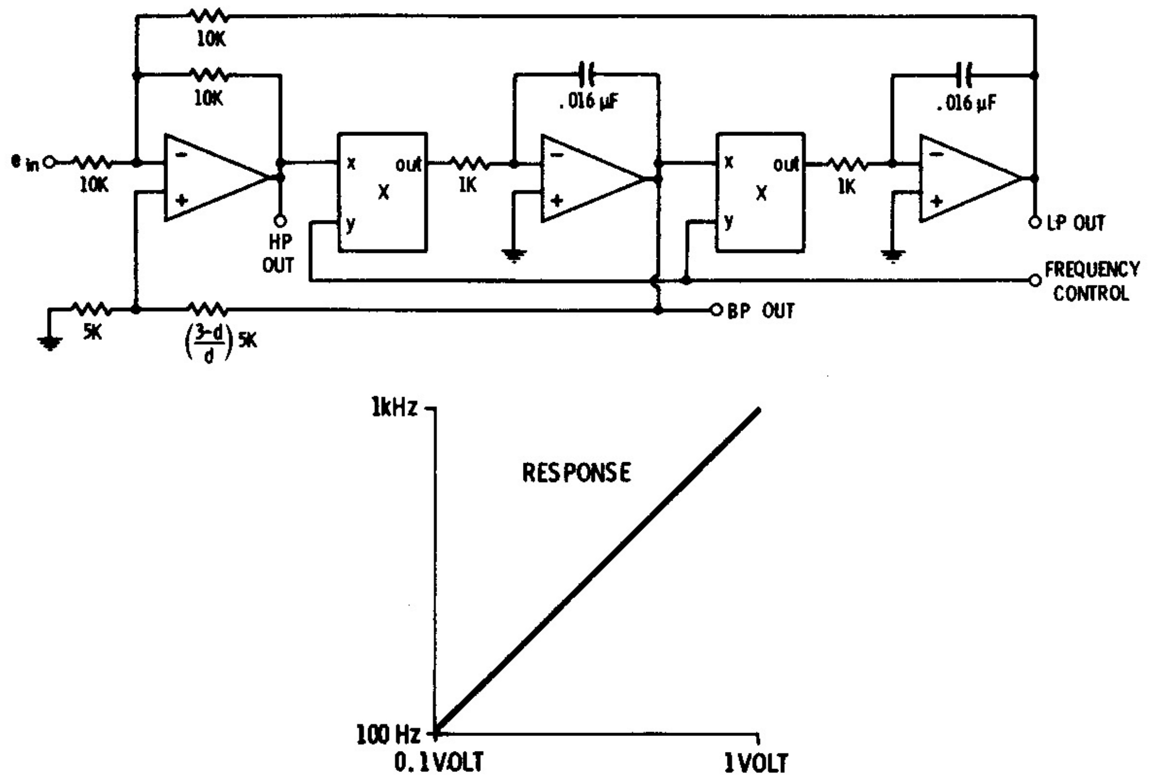
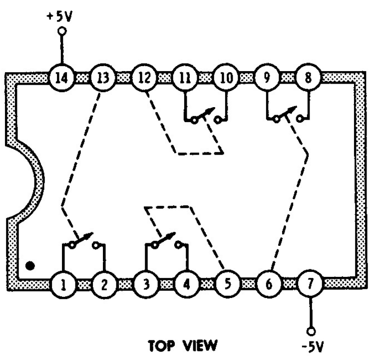


Fig. 9-5. Voltage-controlled filter using IC four-quadrant multipliers.

- Replace integrator input resistors with 2-quadrant multipliers (voltage-controlled amplifiers, or VCA's)
  - Need to tune both VCA's together
    - Results in a wide-range tunable filter!
      - Multiplier can be used to tune Q as well

Switched-Capacitor Tunable Filters

CMOS QUAD BILATERAL SWITCH **4016**

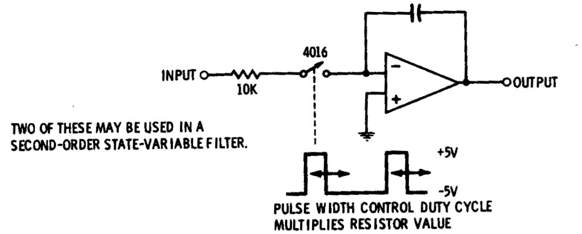


This circuit contains four independent switches that may be used for off-on control of digital or analog signals. Signals to be controlled must be less than +5 and more than −5 volts.

+5 volts applied to pin 13 turns ON the connection between pins 1 and 2. −5 volts applied to pin 13 turns OFF the connection between pins 1 and 2. The other three switches are similarly controlled.

Input impedance to pin 13 is essentially an open circuit. The OFF resistance of pins 1 and 2 is many megohms; the ON resistance is 300 ohms. A lower-impedance, improved version is available as the 4066.

(B) Selecting resistors under digital command (D/A conversion).



(C) Duty-cycle modulator provides variable resistance. Switching rate must be much faster than signal frequencies.

Fig. 9-7. Using the 4016 switch.

Filter Cookbook

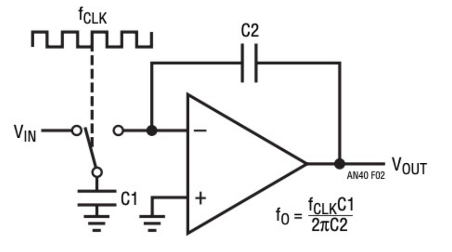


Figure 2. Inverting Switched-Capacitor Integrator

https://www.analog.com/media/en/technical-documentation/application-notes/an40f.pdf

Many types of analog switches are available (e.g., ADG from Analog Devices, etc.)

- R is effectively varied proportionally to the On/Off duty cycle
  - Beware of aliasing (max input frequency is under half the switching frequency)
  - Not for High Pass filters (except in feedback configurations)
- Tend to work best for lower-frequencies

Commercial Tunable Filters

CEM 3350

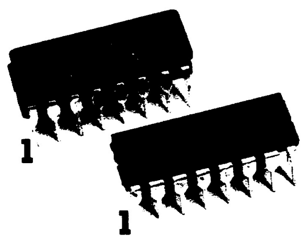
Dual Voltage Controlled State Variable Filter

The CEM 3350 is a dual voltaged controlled state-variable filter intended for electronic musical instruments and other signal processing applications. Each filter provides both voltage control of center/cut-off frequency over more than 12 octaves and voltage control of Q from 1/2 to greater than 40. All control scales are exponential, allowing for easier control of the parameters over their wide range. Although the two filters are completely independent, they may be easily interconnected to form a wide variety of filter responses.

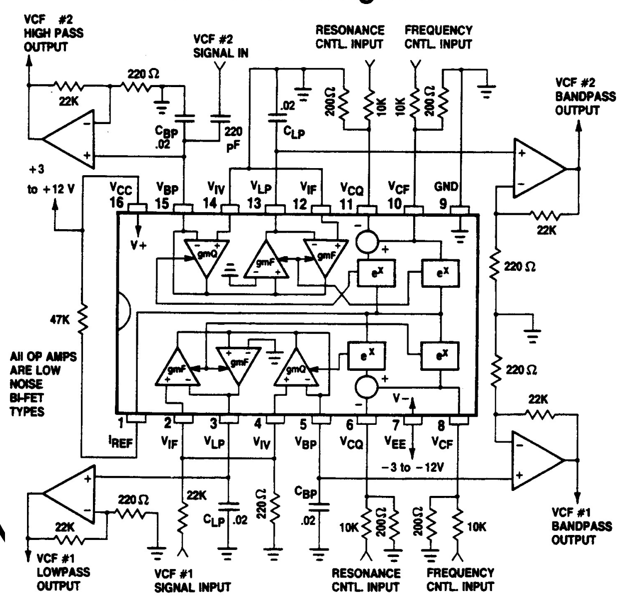
Each filter also provides two signal inputs: For signals applied to the fixed gain input, the output will remain constant as the Q is varied, while for signals applied to the variable gain input, the output decreases as Q is increased. The input signal may be proportioned between these two inputs to provide any desired characteristic.

Finally, each filter provides two simultaneous outputs, making directly available low-pass and band-pass, or band-pass and high-pass responses depending upon where the input signal is applied.

Able to operate over a wide supply range, the versatile CEM 3350 allows new and unique filter responses to be created with a high degree of voltage control over the defining parameters.



Block and Connections Diagram



Features:

- Low Cost
- Two Independent State Variable Filters in a Single 16 Pin DIP
- Separate Frequency and Q Control Inputs for Each
- Wide Frequency Sweep and Q Control Range
- Exponential Control Scales for Both Frequency and Q
- Two Simultaneous Outputs on Each: Low-Pass and Band-Pass or Band-Pass and High-Pass Possible
- Two Simultaneous Inputs for Each: Fixed Gain and Variable Gain
- Chip Configurable Into Many Unique V.C. Filters
- Wide Supply Range: ±3V to ±16V

19-1821; Rev 0; 11/00

$$f_C = \frac{f_{CLK}}{100}$$

MAXIM

5th-Order, Lowpass, Switched-Capacitor Filters

General Description

The MAX7418–MAX7425 5th-order, low-pass, switched-capacitor filters (SCFs) operate from a single +5V (MAX7418–MAX7421) or +3V (MAX7422–MAX7425) supply. These devices draw only 3mA of supply current and allow corner frequencies from 1Hz to 45kHz, making them ideal for low-power post-DAC filtering and anti-aliasing applications. They feature a shutdown mode that reduces supply current to 0.2µA.

Two clocking options are available: self-clocking (through the use of an external capacitor), or external clocking for tighter corner-frequency control. An offset adjust pin allows for adjustment of the DC output level.

The MAX7418/MAX7422 deliver 53dB of stopband rejection and a sharp rolloff with a 1.6 transition ratio. The MAX7421/MAX7425 achieve a sharper rolloff with a 1.25 transition ratio while still providing 37dB of stopband rejection. The MAX7419/MAX7423 Bessel filters provide low overshoot and fast settling, and the MAX7420/MAX7424 Butterworth filters provide a maximally flat passband response. Their fixed response simplifies the design task of selecting a clock frequency.

Applications

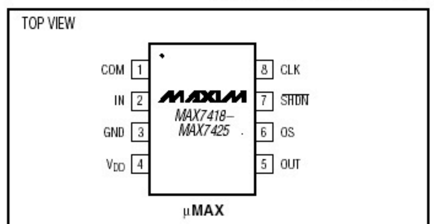
ADC Anti-Aliasing	CT2 Base Stations
DAC Postfiltering	Speech Processing

Selector Guide

PART	FILTER RESPONSE	OPERATING VOLTAGE (V)
MAX7418	r = 1.6	+5
MAX7419	Bessel	+5
MAX7420	Butterworth	+5
MAX7421	r = 1.25	+5

Selector Guide continued at end of data sheet.

Pin Configuration



Features

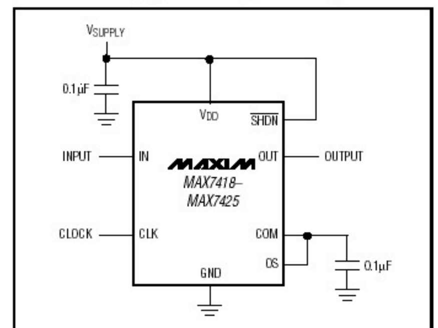
- ♦ 5th-Order, Lowpass Filters
  - Elliptic Response (MAX7418/MAX7421/MAX7422/MAX7425)
  - Bessel Response (MAX7419/MAX7423)
  - Butterworth Response (MAX7420/MAX7424)
- ♦ Clock-Turnable Corner Frequency (1Hz to 45kHz)
- ♦ Single-Supply Operation
  - +5V (MAX7418–MAX7421)
  - +3V (MAX7422–MAX7425)
- ♦ Low Power
  - 3mA (Operating Mode)
  - 0.2µA (Shutdown Mode)
- ♦ Available in 8-Pin µMAX Package
- ♦ Low Output Offset: ±4mV

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX7418CUA	0°C to +70°C	8 µMAX
MAX7418EUA	-40°C to +85°C	8 µMAX
MAX7419CUA	0°C to +70°C	8 µMAX
MAX7419EUA	-40°C to +85°C	8 µMAX
MAX7420CUA	0°C to +70°C	8 µMAX
MAX7420EUA	-40°C to +85°C	8 µMAX
MAX7421CUA	0°C to +70°C	8 µMAX
MAX7421EUA	-40°C to +85°C	8 µMAX

Ordering Information continued at end of data sheet.

Typical Operating Circuit



Commercial Component-Programmed Filters

19-4191; Rev 3; 10/96

MAX274 Evaluation Kit & MAX274/275 Software Manuals Follow Datasheet

MAXIM

4th- and 8th-Order Continuous-Time Active Filters

General Description

The MAX274 and MAX275 are continuous-time active filters consisting of independent cascadable 2nd-order sections. Each section can implement any all-pole bandpass or lowpass filter response, such as Butterworth, Bessel, and Chebyshev, and is programmed by four external resistors. The MAX274/MAX275 provide lower noise than switched-capacitor filters, as well as superior dynamic performance - both due to the continuous-time design. Since continuous-time filters do not require a clock, aliased and clock noise are eliminated with the MAX274/MAX275.

The MAX274 comprises four 2nd-order sections, permitting 8th-order filters to be realized. Center frequencies range up to 150kHz, and are accurate to within ±1% over the full operating temperature range. Total harmonic distortion (THD) is typically better than -89dB.

The MAX275 comprises two 2nd-order sections, permitting 4th-order filters to be realized. Center frequencies range up to 300kHz, and are accurate to within ±0.9% over the full operating temperature range. Total harmonic distortion (THD) is typically better than -86dB.

Both filters operate from a single +5V supply or from dual ±5V supplies.

Applications

Low-Distortion Anti-Aliasing Filters
DAC Output Smoothing Filters
Modems
Audio/Sonar/Avionics Frequency Filtering
Vibration Analysis

Features

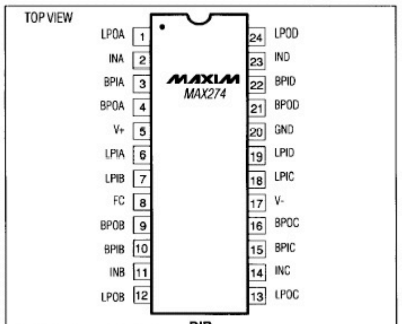
- Continuous-Time Filter - No Clock, No Clock Noise
- Implement Butterworth, Chebyshev, Bessel and Other Filter Responses
- Lowpass, Bandpass Outputs
- Operate from a Single +5V Supply or Dual ±5V Supplies
- Design Software Available
- MAX274 Evaluation Kit Available
- 8th-Order – Four 2nd-Order Sections (MAX274) 4th-Order – Two 2nd-Order Sections (MAX275)
- Center-Frequency Range: 150kHz for MAX274, 300kHz for MAX275
- Low Noise: -86dB THD Typical for MAX274, -89dB THD Typical for MAX275
- Center-Frequency Accurate Over Temp: within ±1% for MAX274, within ±0.9% for MAX275

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX274ACNG	0°C to +70°C	24 Narrow Plastic DIP
MAX274BCNG	0°C to +70°C	24 Narrow Plastic DIP
MAX274ACWI	0°C to +70°C	28 Wide SO
MAX274BCWI	0°C to +70°C	28 Wide SO
MAX274BC/D	0°C to +70°C	Dice*

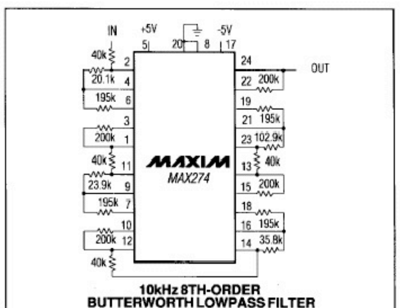
Ordering Information continued on last page
* Contact factory for dice specifications.

Pin Configurations



Pin Configurations continued on last page

Typical Operating Circuits



PIN NUMBERS ARE FOR DIP.
Typical Operating Circuits continued on last page

19-0597; Rev 3; 7/98

MAXIM

Pin Programmable Universal and Bandpass Filters

General Description

The MAX263/264 and MAX267/268 CMOS switched-capacitor active filters are designed for precision filtering applications. Center frequency, Q, and operating mode are all selected via pin-strapped inputs. The MAX263/264 uses no external components for a variety of bandpass, lowpass, highpass, notch and allpass filters. The MAX267/268 is dedicated to bandpass applications and includes an uncommitted op-amp. Two second-order filter sections are included in both devices.

An input clock and a 5-bit programming input precisely set the filter center/corner frequency. Q is also programmed from 0.5 to 64. Separate clock inputs for each filter half operate with either an external clock or a crystal.

The MAX263 and 267 operate with center frequencies up to 57kHz while the MAX264 and 268 extend the f_0 range to 140kHz by employing lower f_{CLK}/f_0 ratios. The MAX263/264 is supplied in 28 pin wide DIP and small outline packages while the MAX267/268 is supplied in 24 pin narrow DIP and wide SO packages. All devices are available in commercial, extended, and military temperature ranges.

Applications

Sonar and Avionics Instruments
Anti-Aliasing Filters
Digital Signal Processing
Vibration and Audio Analysis
Matched Tracking Filters

Features

- Filter Design Software Available
- 32-Step Center Frequency Control
- 128-Step Q Control
- Independent Q and f_0 Programming
- Guaranteed Clock to f_0 Ratio—1% (A grade)
- 75kHz f_0 Range (MAX264/268)
- Single +5V and ±5V Operation

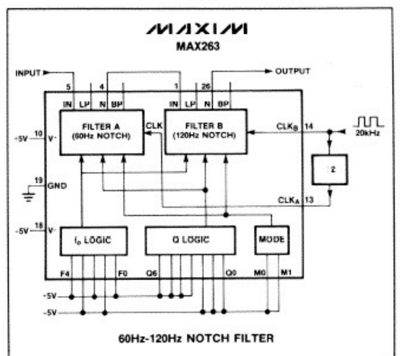
Ordering Information

PART	TEMP. RANGE	PACKAGE*	ACCURACY
MAX263ACPI	0°C to +70°C	Plastic DIP	1%
MAX263BCPI	0°C to +70°C	Plastic DIP	2%
MAX263AEPI	-40°C to +85°C	Plastic DIP	1%
MAX263BEPI	-40°C to +85°C	Plastic DIP	2%
MAX263ACWI	0°C to +70°C	Wide SO	1%
MAX263BCWI	0°C to +70°C	Wide SO	2%
MAX263AMJI	-55°C to +125°C	CERDIP	1%
MAX263BMJI	-55°C to +125°C	CERDIP	2%
MAX264ACPI	0°C to +70°C	Plastic DIP	1%
MAX264BCPI	0°C to +70°C	Plastic DIP	2%

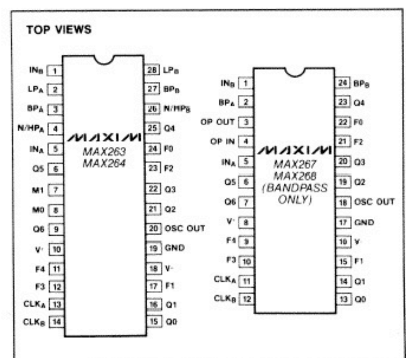
(Ordering Information continued at end of data sheet.)

* MAX263/264 packages are 28-pin 0.6" wide DIP and 28-pin 0.3" wide SO (Small Outline).
MAX267/268 packages are 24-pin 0.3" narrow DIP and 24-pin 0.3" wide SO (Small Outline).

Typical Application



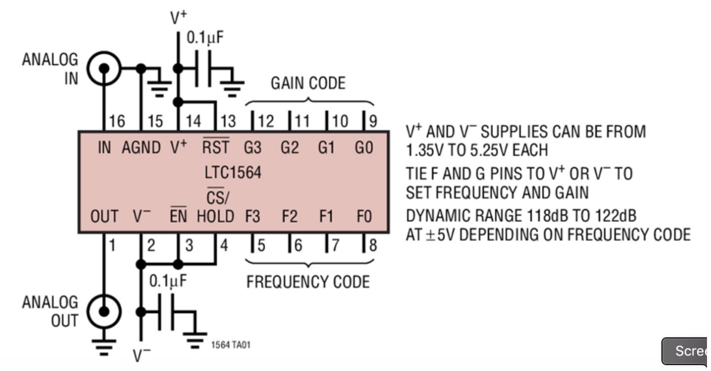
Pin Configuration



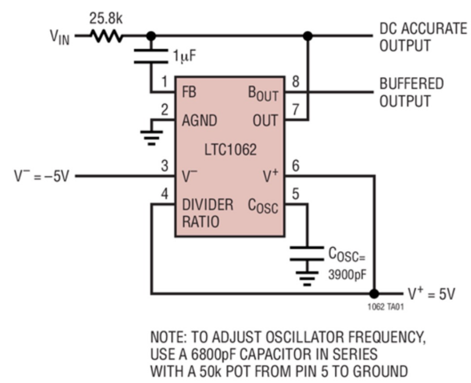
Resistor-Programmable *Pin-Programmable*

Filters from Hong

Low Noise Programmable Filter with Variable Gain



10Hz 5th Order Butterworth Lowpass Filter



LTC1564 Tunable low pass filter 10kHz to 150kHz in steps of 10kHz, 8 pole roll-off, programmable 1-16 gain, 3-10V operation.

LTC1062 parallel 5-pole tunable low pass filter. Absolutely zero DC error because the input and output are connected directly with a wire and the filter damps out the high frequencies.

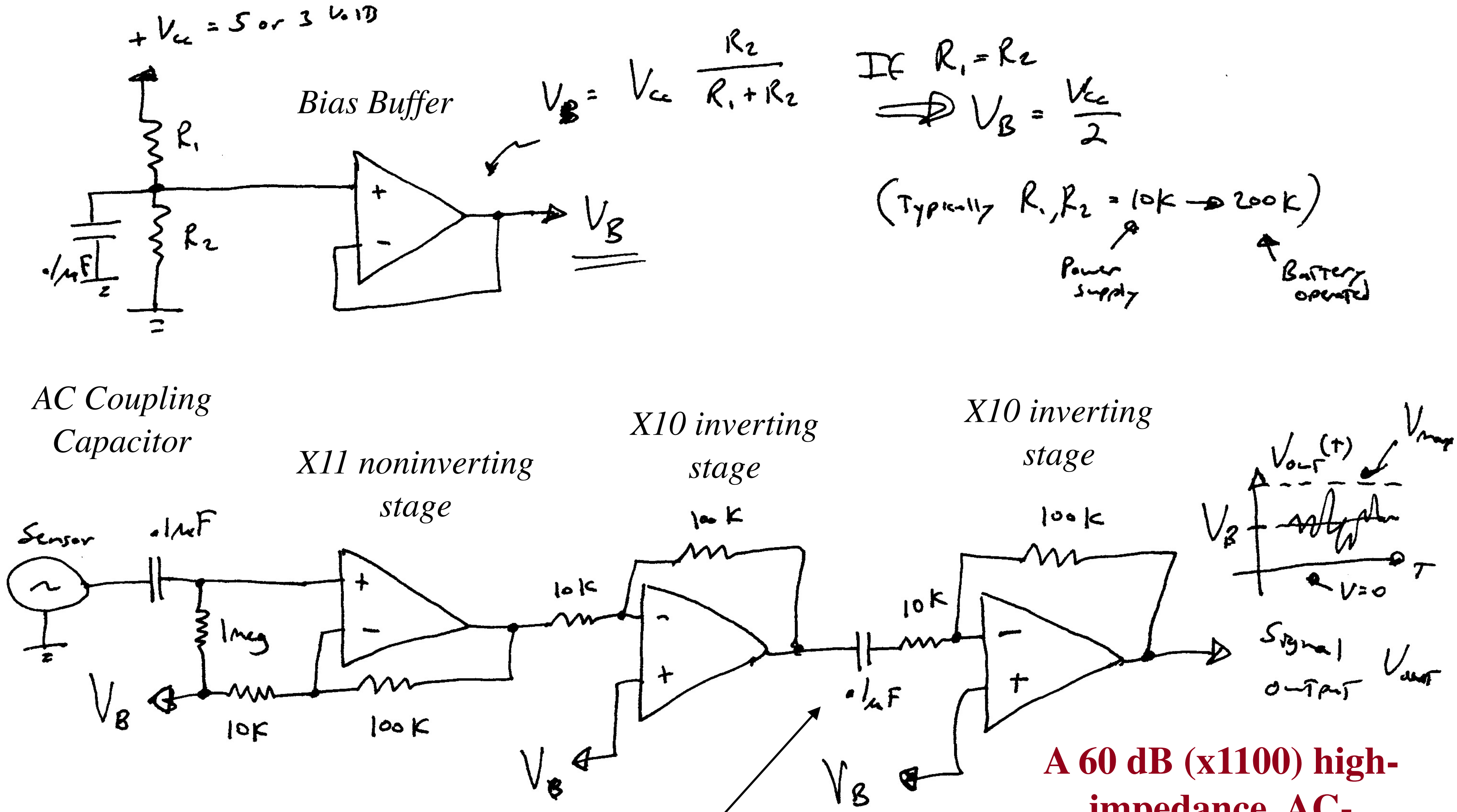
Note – from 2002!

Biasing

- AC Coupling
- Biasing noninverting input
- Biasing at inverting input

Buffer the voltage divider's output and use it everywhere…

Biasing an entire circuit with a Buffered Voltage

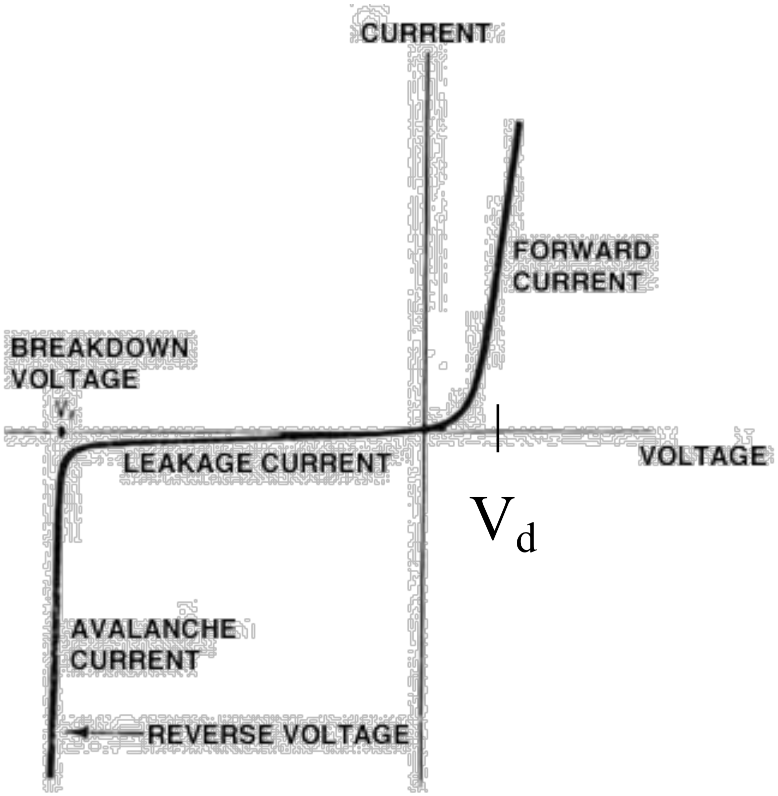


AC Coupling Capacitor (decouple accumulated offset errors)

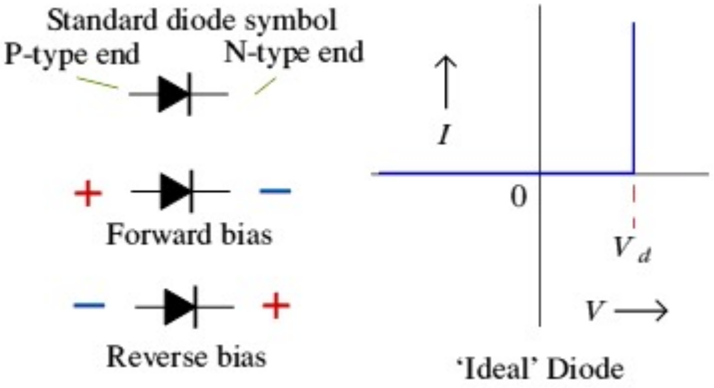
A 60 dB (x1100) high-impedance, AC-Coupled amplifier with bias made from a quad OpAmp

Diodes

- The Diode
  - I/V characteristic, ideal diode, forward drop, zeners

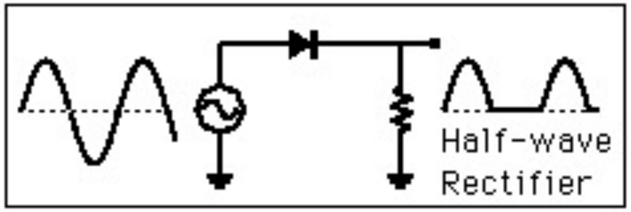


Drops (V_d):
Si = 0.6 V
Ge = 0.3 V
LED = 2.4-3.5 V
Schottky = .1-.3 V

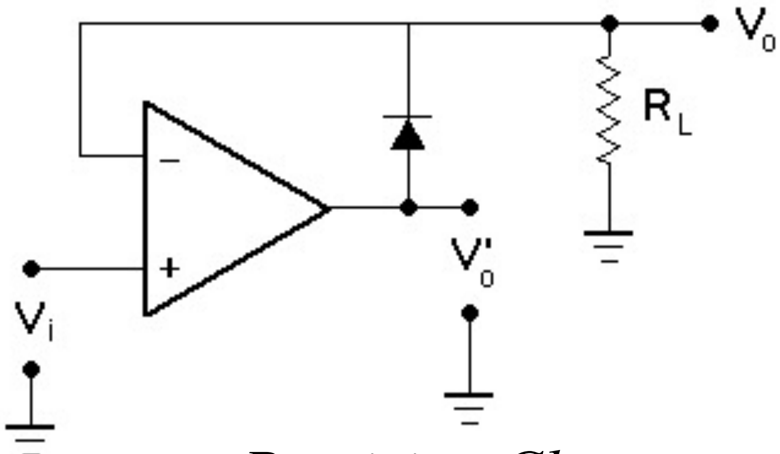


Basic Diode Circuits

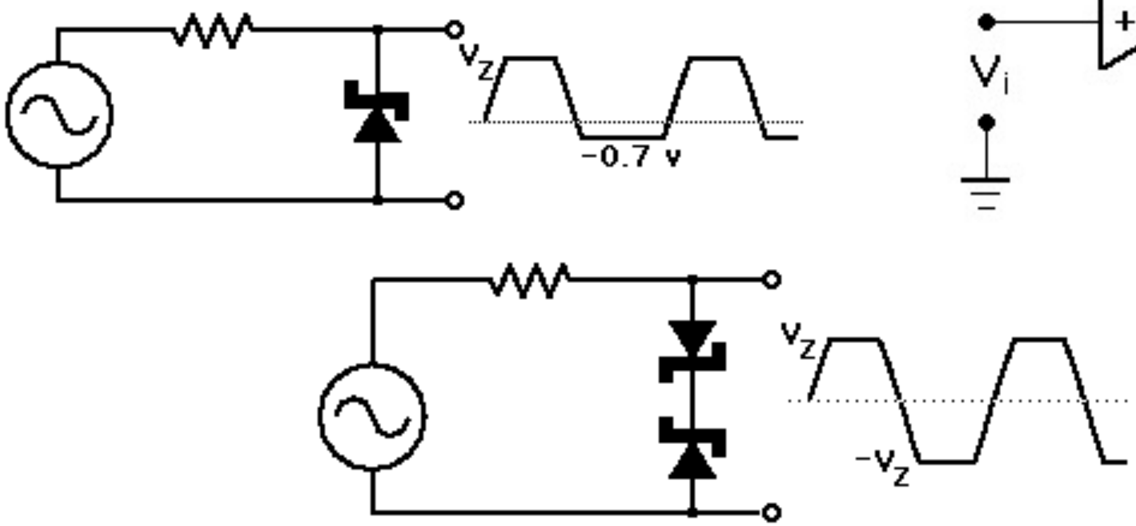
- Limiters/Clampers
  - –Passive Limiter - normal and zener
  - –Precision Zener



Positive Clamper

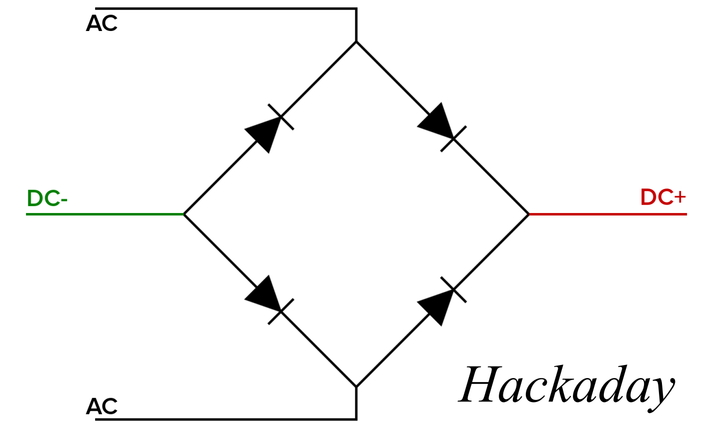


Precision Clamper
(servos out 0.6 V drop)

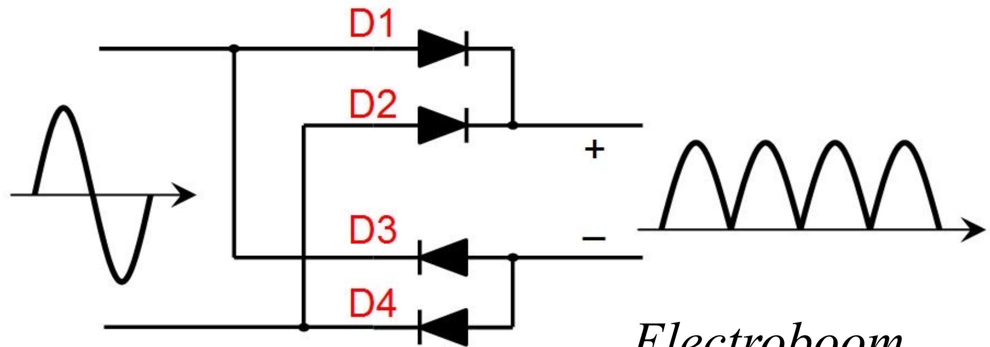


Zener Limiters

Bridge Rectifiers –> Absolute Value



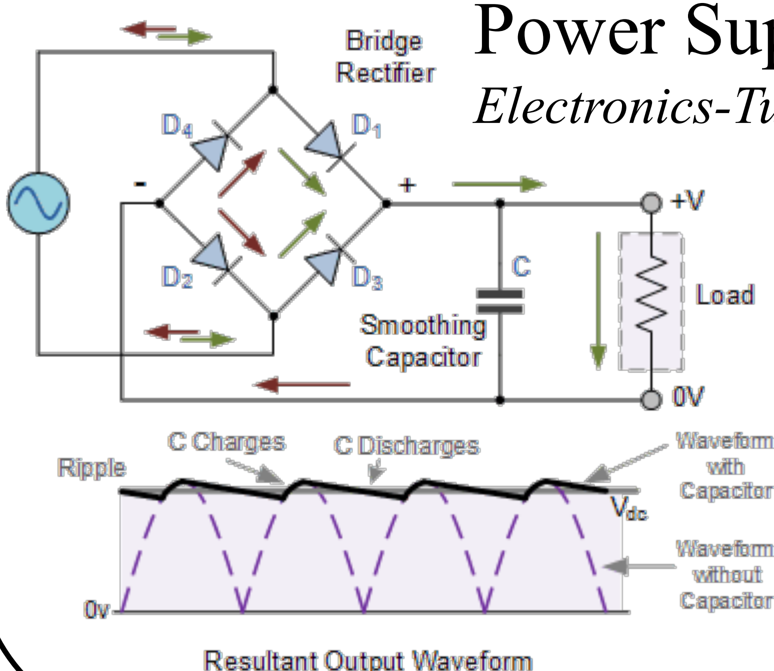
Hackaday



Electroboom

Power Supply

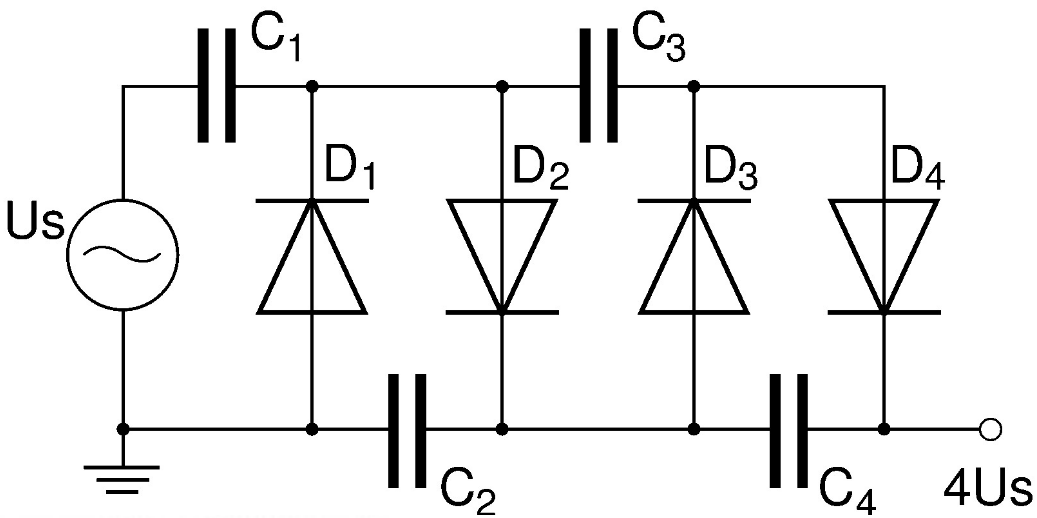
Electronics-Tutorials

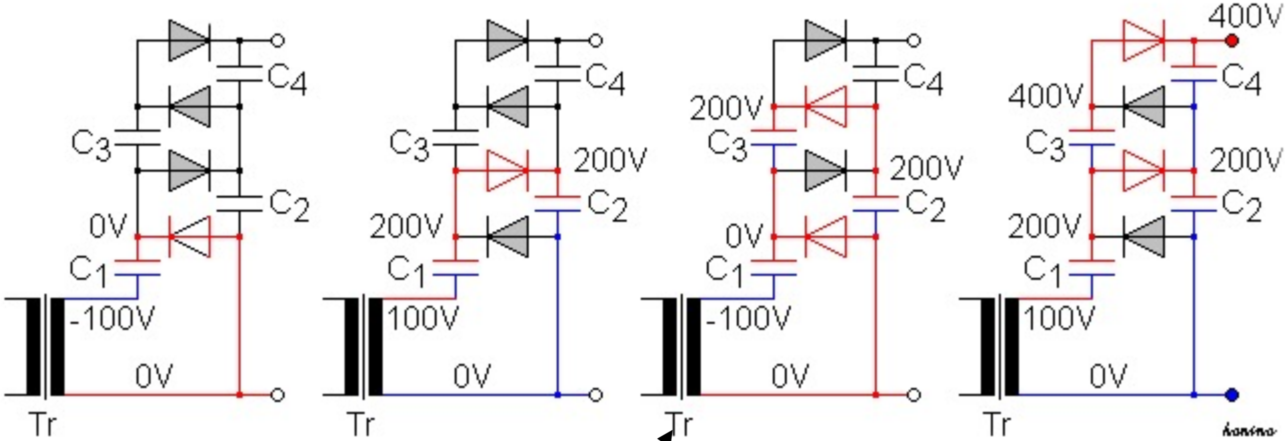


0.6 V diode drop x2!

Voltage Multipliers, etc.

Cascaded Villard doubler



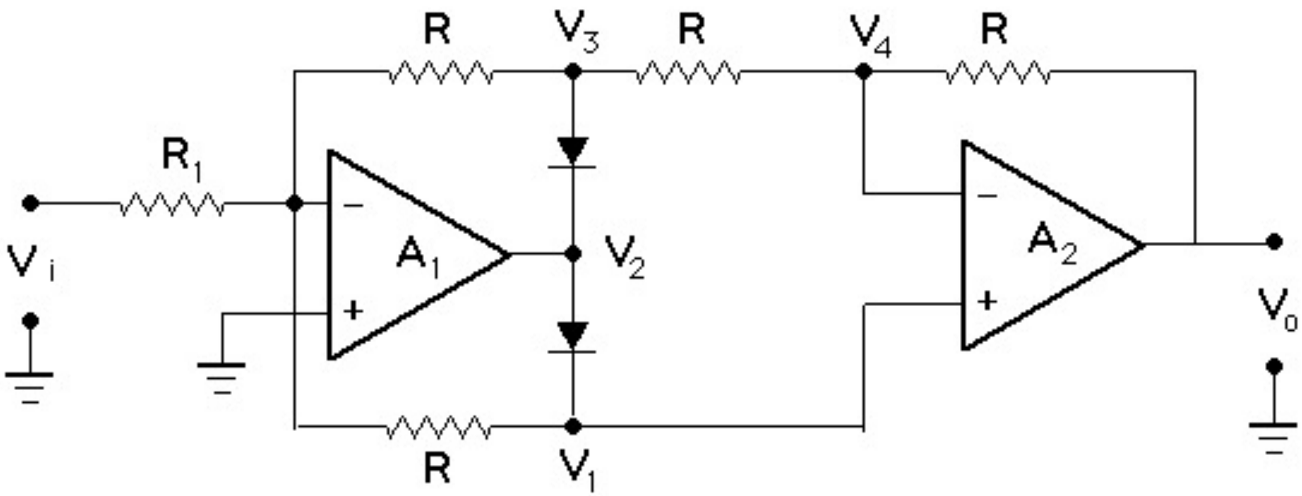


Ref: Wikipedia…

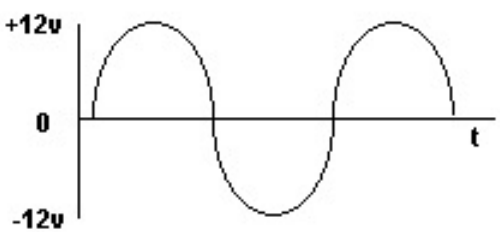
Transformer for isolation

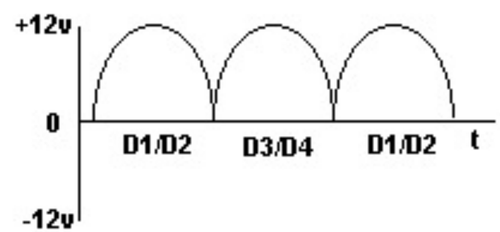
- Diodes don't let capacitors discharge onto source
- AC coupling lets each peak sit atop capacitor voltage
-Each AC peak increments voltage by half-wave height
- Voltage drop at given current increases rapidly (cube) with no. stages, inversely with C, freq

Absolute Value Circuits



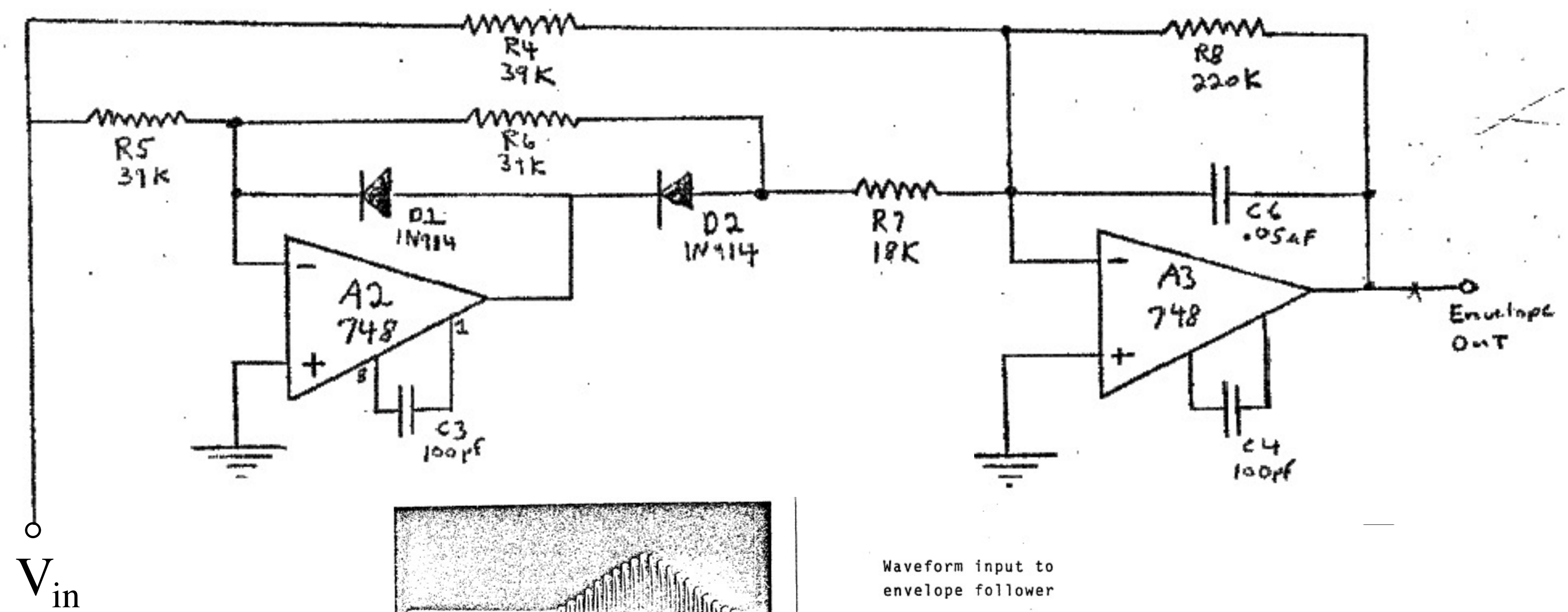
Full Wave Rectifier Circuit

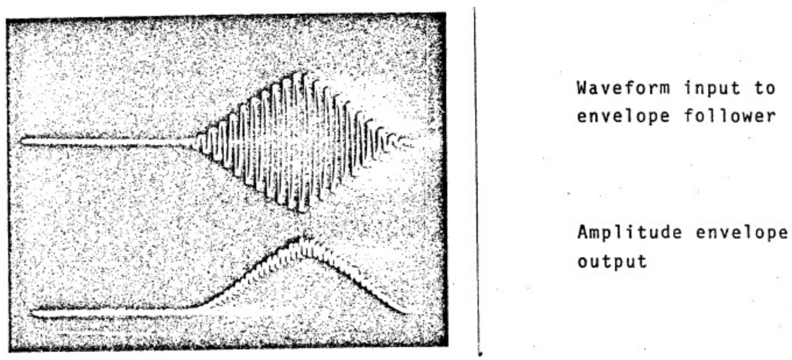




Bottom R is 2/3 top R in A_1?

Absolute Value Circuit (envelope follower)





- A1 and A2 form an absolute value detector
- C6 integrates the absolute value to give the envelope
- Note that the 748 (and its compensation cap) is long obsolete!

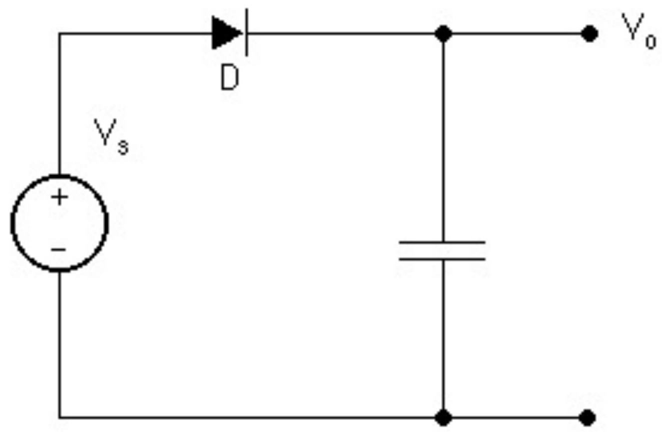
Sampling

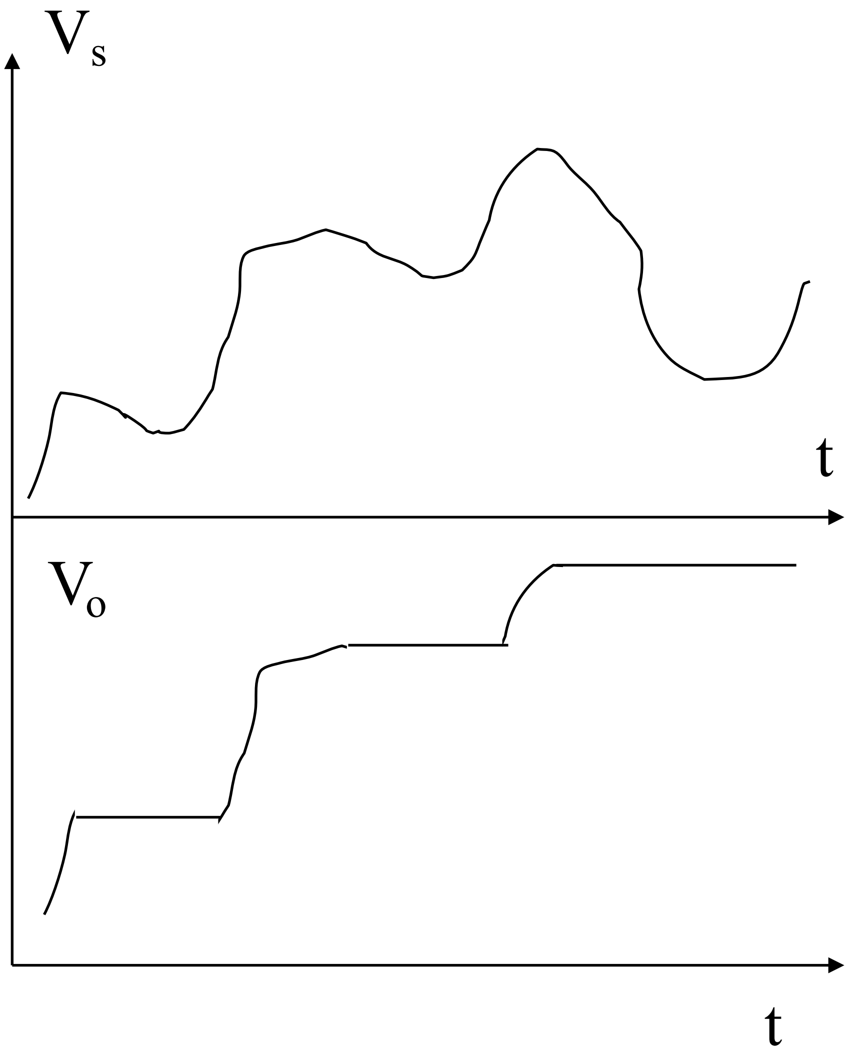
- Nyquist: $f_{in} < f_s/2$
- Bandlimited (demodulation) sampling
  - $\Delta f_{in} < f_s/2$
  - Loose absolute phase information
    - Don't know whether phase moves forward or backward
  - Quadrature sampling
    - Bandlimited sampling at t and a quarter-period later

Sampling Aids

- Aliasing for nonperiodic signals??
  - Can miss or miss-sample trasients!
  - The Pulse-stretcher to the rescue!
- Sample/Holds
- Analog Multiplexers
- Programmable Gain Amplifiers (PGA's)
- Voltage-Controlled Amplifiers (VCA's)

Peak Detector

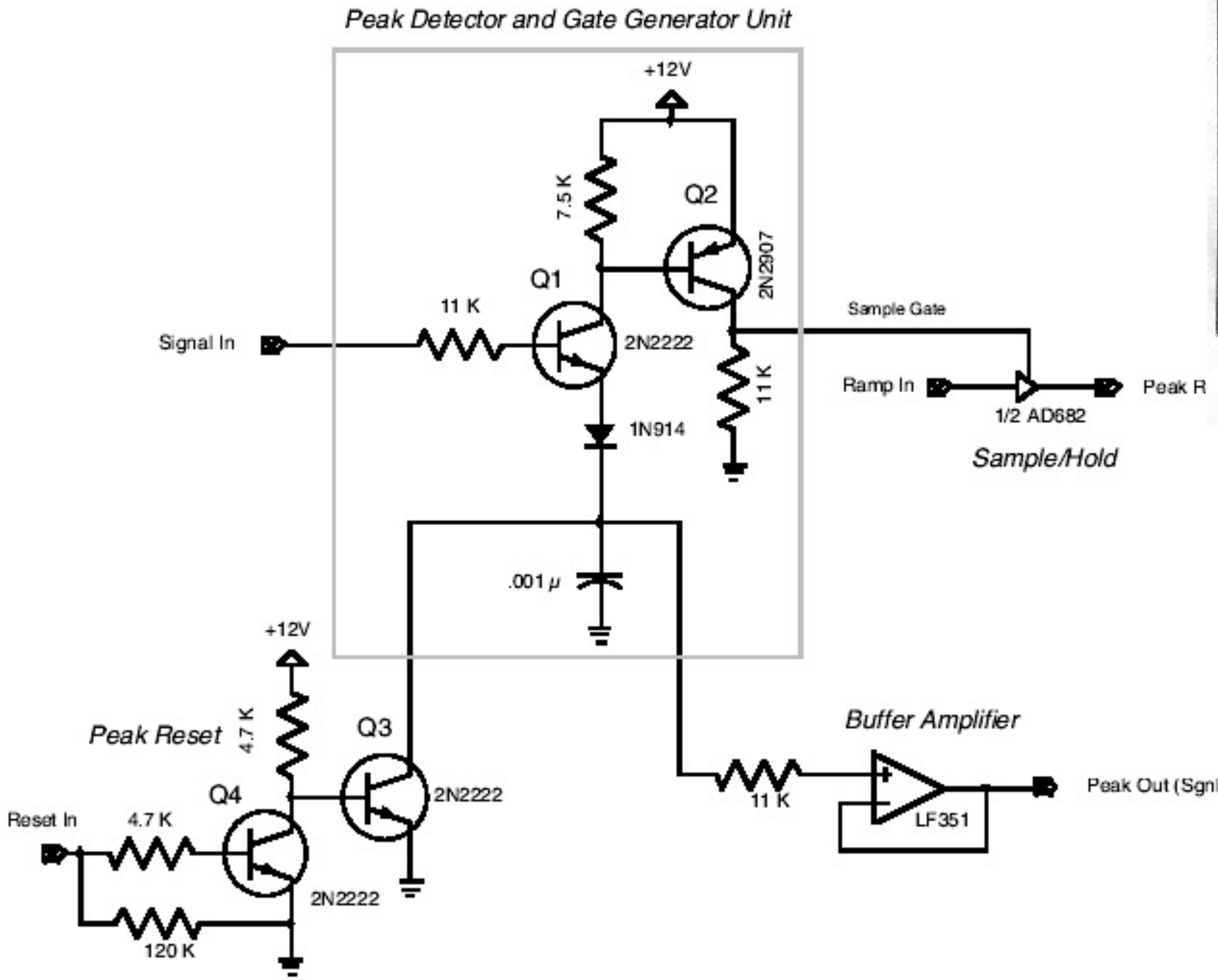


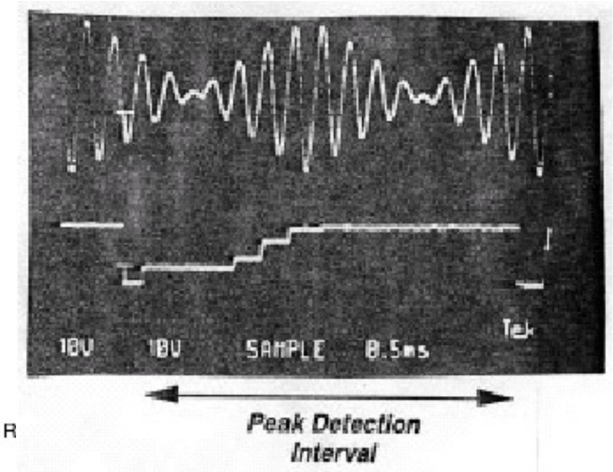


Capacitor holds peaks!

Need reset switch to continue tracking

Peak Detector w. Reset and Gate





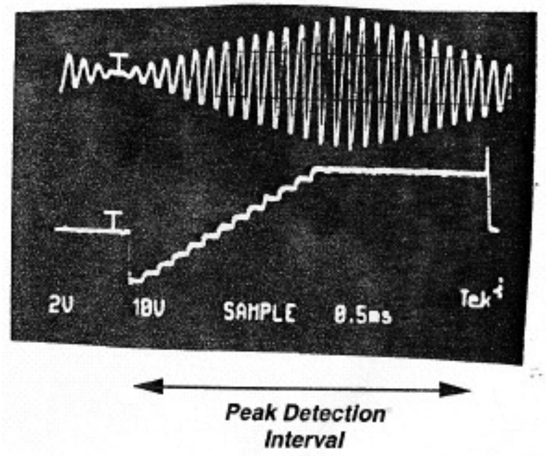
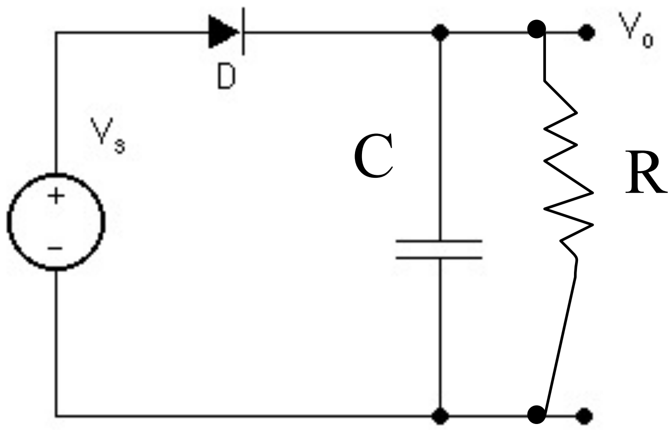


Fig. 4: Peak Sampler Circuit Constructed for Tests

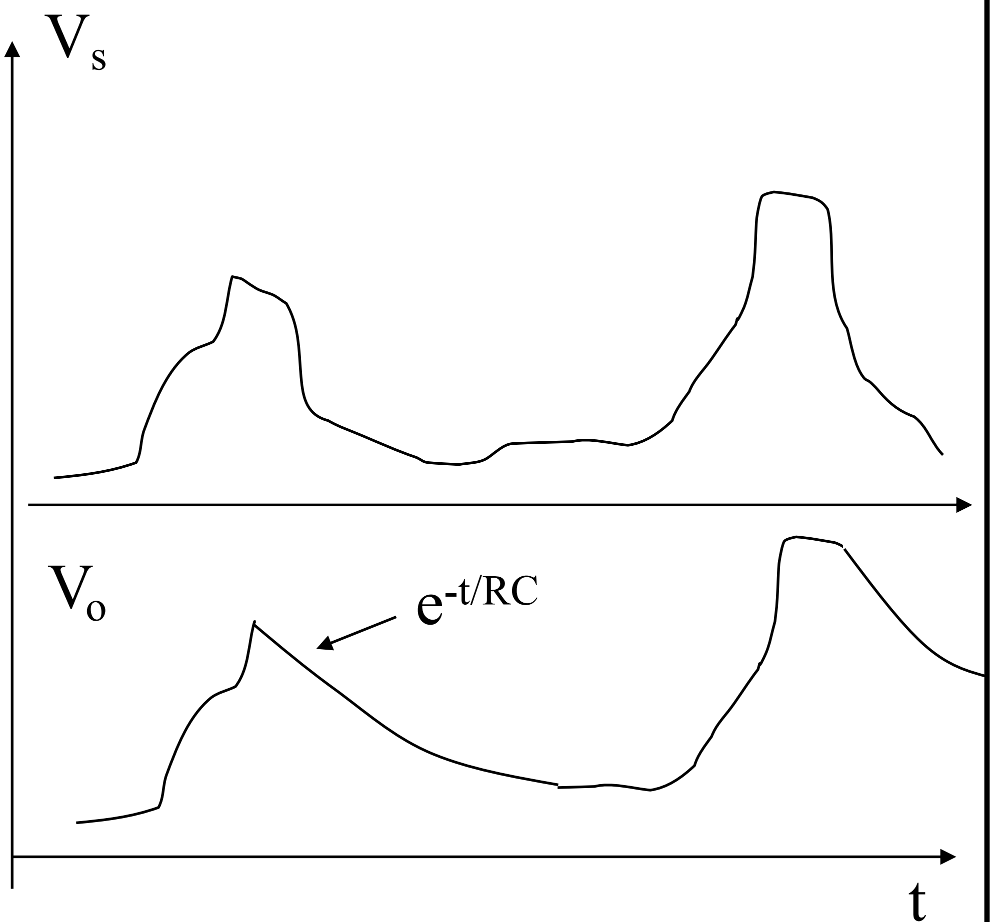
Pulse Stretcher



-Resistor continually (and slowly) bleeds capacitor charge

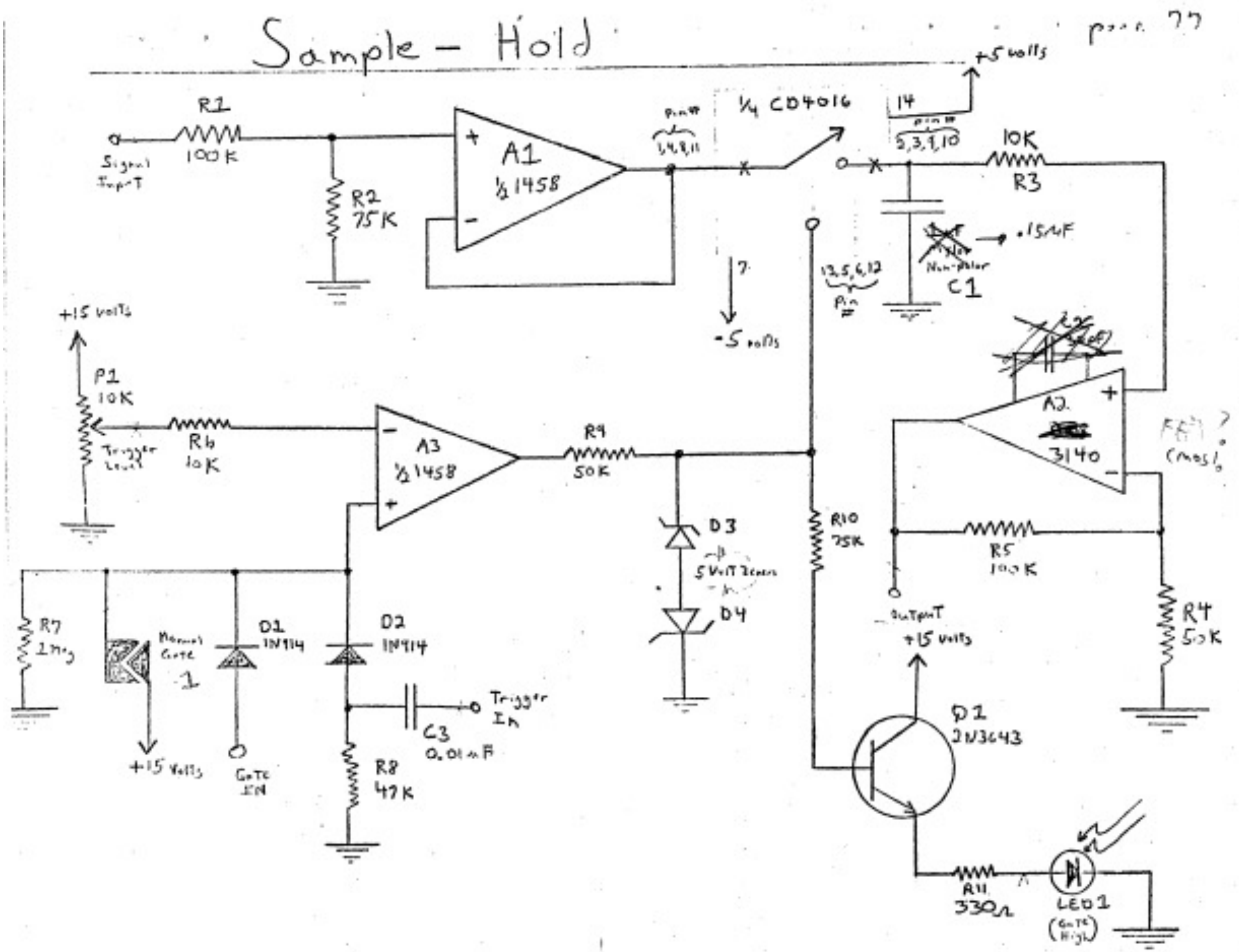
-Automatic "reset"

-Tune time constant to match signal dynamics (so peaks are always followed)

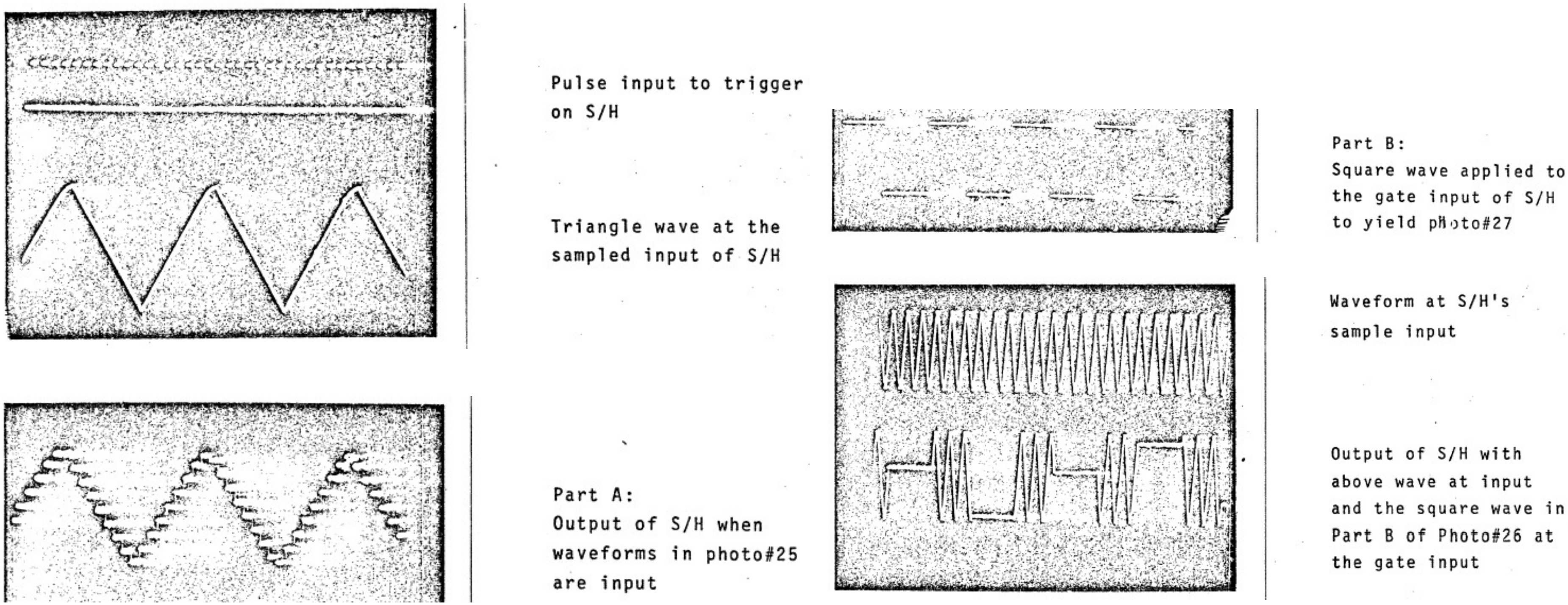


-Enables "lazy" sampling to catch transients

The Basic Sample-Hold Circuit



The Sample-Hold (and Track-Hold)



- Sample-Hold grabs input signal and holds it upon receipt of a pulse edge
- Track-Hold follows the input signal when the gate is high, but holds (latches) it when the gate is low.
- Sample hold acquires quickly – can use slow ADC.

Sample-Holds

LF198/LF298/LF398, LF198A/LF398A Monolithic Sample-and-Hold Circuits

General Description

The LF198/LF298/LF398 are monolithic sample-and-hold circuits which utilize BI-FET technology to obtain ultra-high dc accuracy with fast acquisition of signal and low droop rate. Operating as a unity gain follower, dc gain accuracy is 0.002% typical and acquisition time is as low as 6 µs to 0.01%. A bipolar input stage is used to achieve low offset voltage and wide bandwidth. Input offset adjust is accomplished with a single pin, and does not degrade input offset drift. The wide bandwidth allows the LF198 to be included inside the feedback loop of 1 MHz op amps without having stability problems. Input impedance of $10^{10}\Omega$ allows high source impedances to be used without degrading accuracy.

P-channel junction FET's are combined with bipolar devices in the output amplifier to give droop rates as low as 5 mV/min with a 1 µF hold capacitor. The JFET's have much lower noise than MOS devices used in previous designs and do not exhibit high temperature instabilities. The overall design guarantees no feed-through from input to output in the hold mode, even for input signals equal to the supply voltages.

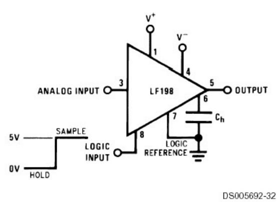
Features

- Operates from ±5V to ±18V supplies
- Less than 10 µs acquisition time
- TTL, PMOS, CMOS compatible logic input
- 0.5 mV typical hold step at C_h = 0.01 µF
- Low input offset
- 0.002% gain accuracy
- Low output noise in hold mode
- Input characteristics do not change during hold mode
- High supply rejection ratio in sample or hold
- Wide bandwidth
- Space qualified, JM38510

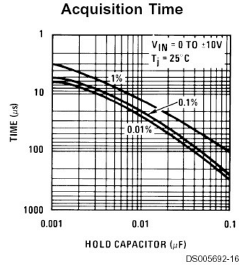
Logic inputs on the LF198 are fully differential with low input current, allowing direct connection to TTL, PMOS, and CMOS. Differential threshold is 1.4V. The LF198 will operate from ±5V to ±18V supplies.

An "A" version is available with tightened electrical specifications.

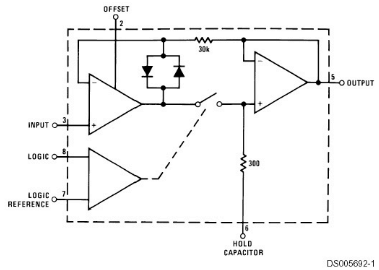
Typical Connection and Performance Curve



Acquisition Time



Functional Diagram



Simple, 1-channel, ext. cap

19-1469; Rev 0; 7/99

MAXIM

32-Channel Sample/Hold Amplifier with a Single Multiplexed Input

General Description

The MAX5165 contains four 1-to-8 multiplexers and 32 sample/hold amplifiers. A single analog input connects to all four internal 1-to-8 multiplexers. The sample/hold amplifiers are organized into four octal sample/holds with independent TTL/CMOS-compatible track/hold enables for each octal set. Additional 3-bit TTL/CMOS-compatible address logic selects the 1-to-8 multiplexer channel. Clamping diodes on each output allow clamping between two external reference voltages. The MAX5165 is available with an output impedance of 50Ω, 500Ω, or 1kΩ, allowing output filtering.

The MAX5165 operates with +10V and -5V supplies and a separate +5V digital logic supply. Manufactured with a proprietary BiCMOS process, it provides high accuracy, fast acquisition time, low droop rate, and a low hold step. The device acquires 8V step input signals to 0.01% accuracy in 2.5µs. Transitions from sample mode to hold mode result in only a 0.5mV error. While in hold mode, the output voltage slowly droops at a rate of 1mV/sec. The MAX5165 is available in a 48-pin TQFP package.

Applications

Automatic Test Equipment (ATE)
Industrial Process Controls
Arbitrary Function Generators
Avionics Equipment

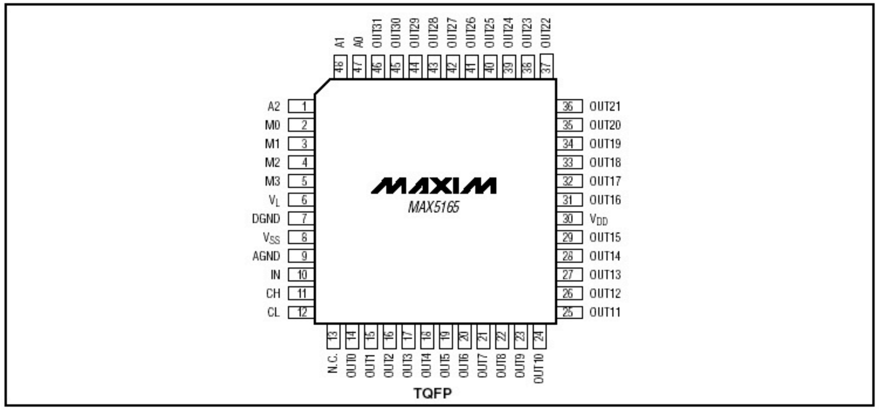
Features

- 32-Channel Sample/Hold
- Output Clamping
- 0.01% Accuracy of Acquired Signal
- 0.01% Linearity Error
- Fast Acquisition Time: 2.5µs
- Low Droop Rate: 1mV/sec
- Low Hold Step: 0.25mV
- Wide Output Voltage Range: +7V to -4V

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE	R_{OUT} (Ω)
MAX5165LCCM	0°C to +70°C	48 TQFP	50
MAX5165MCCM	0°C to +70°C	48 TQFP	500
MAX5165NCCM	0°C to +70°C	48 TQFP	1k
MAX5165LECM	-40°C to +85°C	48 TQFP	50
MAX5165MECM	-40°C to +85°C	48 TQFP	500
MAX5165NECM	-40°C to +85°C	48 TQFP	1k

Pin Configuration



Multiple S/H on one input for fast acquisition

Analog Multiplexers

CD4051BM/CD4051BC Single 8-Channel Analog Multiplexer/Demultiplexer
CD4052BM/CD4052BC Dual 4-Channel Analog Multiplexer/Demultiplexer
CD4053BM/CD4053BC Triple 2-Channel Analog Multiplexer/Demultiplexer

General Description

These analog multiplexers/demultiplexers are digitally controlled analog switches having low "ON" impedance and very low "OFF" leakage currents. Control of analog signals up to $15V_{p\text{-}p}$ can be achieved by digital signal amplitudes of 3–15V. For example, if $V_{DD}=5V$, $V_{SS}=0V$ and $V_{EE}=-5V$, analog signals from −5V to +5V can be controlled by digital inputs of 0–5V. The multiplexer circuits dissipate extremely low quiescent power over the full $V_{DD}-V_{SS}$ and $V_{DD}-V_{EE}$ supply voltage ranges, independent of the logic state of the control signals. When a logical "1" is present at the inhibit input terminal all channels are "OFF".

CD4051BM/CD4051BC is a single 8-channel multiplexer having three binary control inputs, A, B, and C, and an inhibit input. The three binary signals select 1 of 8 channels to be turned "ON" and connect the input to the output.

CD4052BM/CD4052BC is a differential 4-channel multiplexer having two binary control inputs, A and B, and an inhibit input. The two binary input signals select 1 or 4 pairs of channels to be turned on and connect the differential analog inputs to the differential outputs.

CD4053BM/CD4053BC is a triple 2-channel multiplexer having three separate digital control inputs, A, B, and C, and an inhibit input. Each control input selects one of a pair of channels which are connected in a single-pole double-throw configuration.

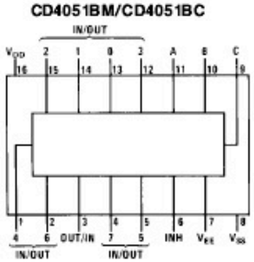
Features

- Wide range of digital and analog signal levels: digital 3–15V, analog to $15V_{p\text{-}p}$
- Low "ON" resistance: 80Ω (typ.) over entire $15V_{p\text{-}p}$ signal-input range for $V_{DD}-V_{EE}=15V$
- High "OFF" resistance: channel leakage of ±10 pA (typ.) at $V_{DD}-V_{EE}=10V$
- Logic level conversion for digital addressing signals of 3–15V ($V_{DD}-V_{SS}=3\text{–}15V$) to switch analog signals to 15 $V_{p\text{-}p}$ ($V_{DD}-V_{EE}=15V$)
- Matched switch characteristics: $\Delta R_{ON}=5\Omega$ (typ.) for $V_{DD}-V_{EE}=15V$
- Very low quiescent power dissipation under all digital-control input and supply conditions: 1 μW (typ.) at $V_{DD}-V_{SS}=V_{DD}-V_{EE}=10V$
- Binary address decoding on chip

Connection Diagrams

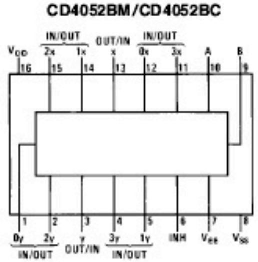
Dual-In-Line Packages

CD4051BM/CD4051BC



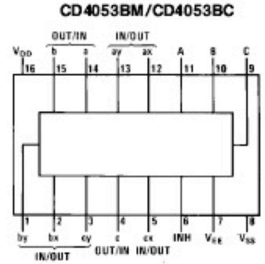
TOP VIEW

CD4052BM/CD4052BC



TOP VIEW

CD4053BM/CD4053BC



TOP VIEW

TL/F/5662–1

Order Number CD4051B, CD4052B, or CD4053B

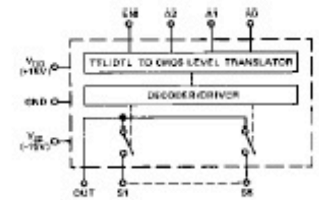
ANALOG DEVICES

CMOS 4-/8-Channel Analog Multiplexers

AD7501/AD7502/AD7503

FEATURES
DTL/TTL/CMOS Direct Interface
Power Dissipation: 30 μW
R_{ON}: 170 Ω
Standard 16-Lead DIPs and 20-Terminal Surface Mount Packages

FUNCTIONAL BLOCK DIAGRAM
AD7501/AD7503

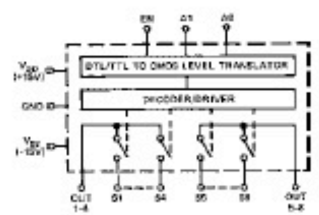


GENERAL DESCRIPTION

The AD7501 and AD7503 are monolithic CMOS, 8-channel analog multiplexers which switch one of eight inputs to a common output, depending on the state of three binary address lines and an "enable" input. The AD7503 is identical to the AD7501 except its "enable" logic is inverted. All digital inputs are TTL/DTL and CMOS logic compatible.

The AD7502 is a monolithic CMOS dual 4-channel analog multiplexer. Depending on the state of two binary address inputs and an "enable," it switches two output buses to two of eight inputs.

AD7502



Truth Tables

AD7501

A_2	A_1	A_0	EN	"ON"
0	0	0	1	1
0	0	1	1	2
0	1	0	1	3
0	1	1	1	4
1	0	0	1	5
1	0	1	1	6
1	1	0	1	7
1	1	1	1	8
X	X	X	0	None

AD7503

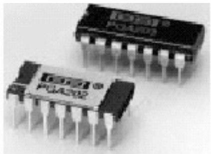
A_2	A_1	A_0	EN	"ON"
0	0	0	0	1
0	0	1	0	2
0	1	0	0	3
0	1	1	0	4
1	0	0	0	5
1	0	1	0	6
1	1	0	0	7
1	1	1	0	8
X	X	X	1	None

AD7502

A_1	A_0	EN	"ON"
0	0	1	1 & 5
0	1	1	2 & 6
1	0	1	3 & 7
1	1	1	4 & 8
X	X	0	None

Programmable Gain Amplifiers

BURR-BROWN®



PGA202/203

Digitally Controlled Programmable-Gain INSTRUMENTATION AMPLIFIER

FEATURES

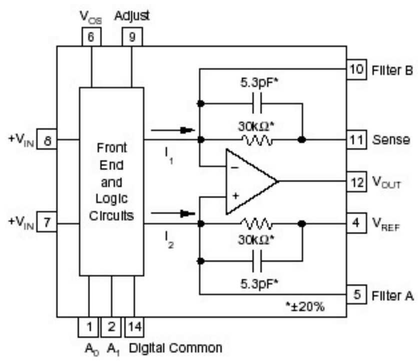
- DIGITALLY PROGRAMMABLE GAINS:
  DECADE MODEL—PGA202
  GAINS OF 1, 10, 100, 1000
  BINARY MODEL—PGA203
  GAINS OF 1, 2, 4, 8
- LOW BIAS CURRENT: 50pA max
- FAST SETTLING: 2µs to 0.01%
- LOW NON-LINEARITY: 0.012% max
- HIGH CMRR: 80dB min
- NEW TRANSCONDUCTANCE CIRCUITRY
- LOW COST

APPLICATIONS

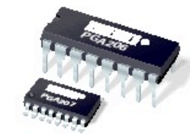
- DATA ACQUISITION SYSTEMS
- AUTO-RANGING CIRCUITS
- DYNAMIC RANGE EXPANSION
- REMOTE INSTRUMENTATION
- TEST EQUIPMENT

DESCRIPTION

The PGA202 is a monolithic instrumentation amplifier with digitally controlled gains of 1, 10, 100, and 1000. The PGA203 provides gains of 1, 2, 4, and 8. Both have TTL or CMOS-compatible inputs for easy microprocessor interface. Both have FET inputs and a new transconductance circuitry that keeps the bandwidth nearly constant with gain. Gain and offsets are laser trimmed to allow use without any external components. Both amplifiers are available in ceramic or plastic packages. The ceramic package is specified over the full industrial temperature range while the plastic package covers the commercial range.



BURR-BROWN®



PGA206 PGA207

High-Speed Programmable Gain INSTRUMENTATION AMPLIFIER

FEATURES

- DIGITALLY PROGRAMMABLE GAINS:
  PGA206: G=1, 2, 4, 8V/V
  PGA207: G=1, 2, 5, 10V/V
- TRUE INSTRUMENTATION AMP INPUT
- FAST SETTLING: 3.5µs to 0.01%
- FET INPUT: I_B = 100pA max
- INPUT PROTECTION: ±40V
- LOW OFFSET VOLTAGE: 1.5mV max
- 16-PIN DIP, SOL-16 SOIC PACKAGES

APPLICATIONS

- MULTIPLE-CHANNEL DATA ACQUISITION
- MEDICAL, PHYSIOLOGICAL AMPLIFIER
- PC-CONTROLLED ANALOG INPUT BOARDS

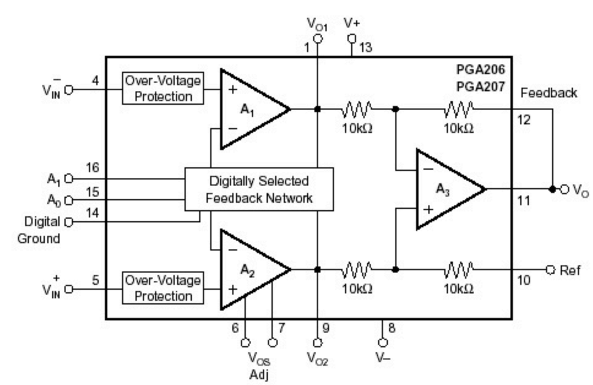
DESCRIPTION

The PGA206 and PGA207 are digitally programmable gain instrumentation amplifiers that are ideally suited for data acquisition systems.

The PGA206 and PGA207's fast settling time allows multiplexed input channels for excellent system efficiency. FET inputs eliminate I_B errors due to analog multiplexer series resistance.

Gains are selected by two CMOS/TTL-compatible address lines. Analog inputs are internally protected for overloads up to ±40V, even with the power supplies off. The PGA206 and PGA207 are laser-trimmed for low offset voltage and low drift.

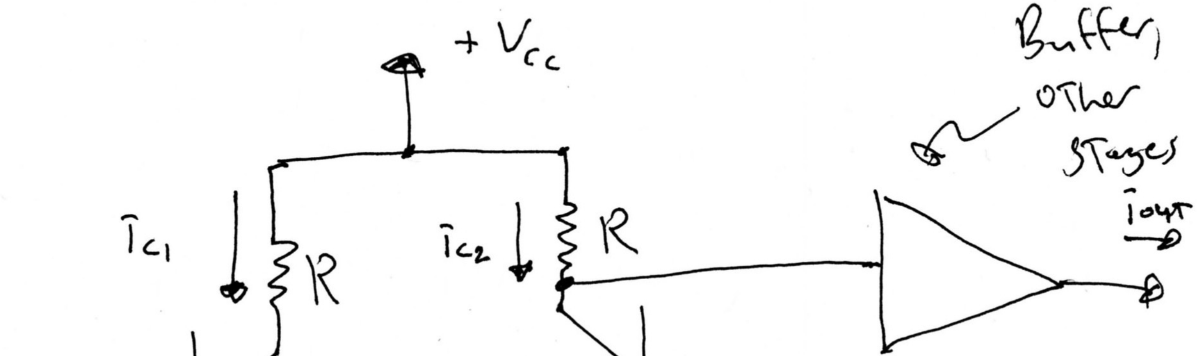
The PGA206 and PGA207 are available in 16-pin plastic DIP and SOL-16 surface-mount packages. Both are specified for –40°C to +85°C operation.

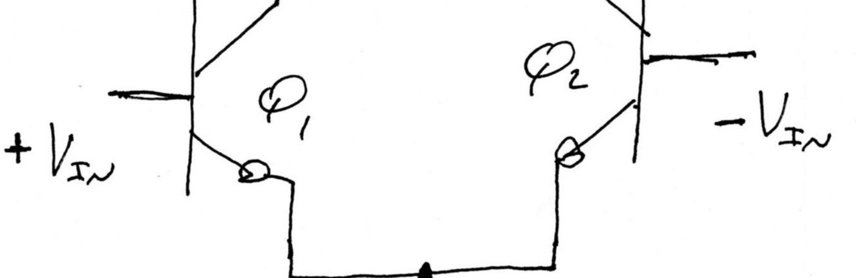


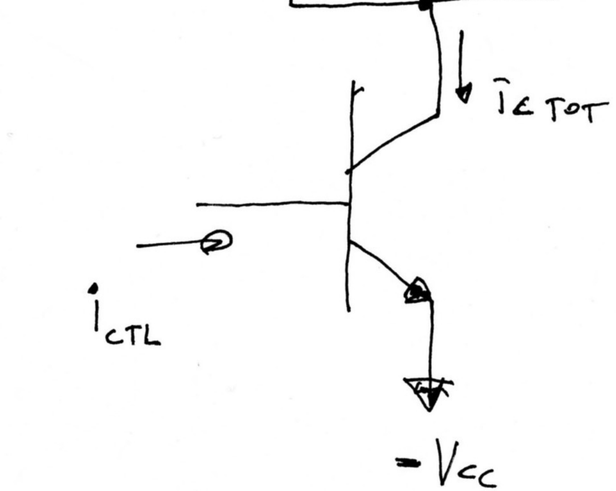
Front end of the OTA

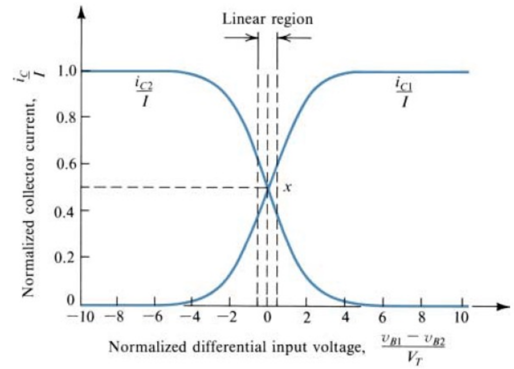
$$I_{ctot} = i_{c1} + i_{c2} = \beta i_{CTL}$$

OTAs have current outputs





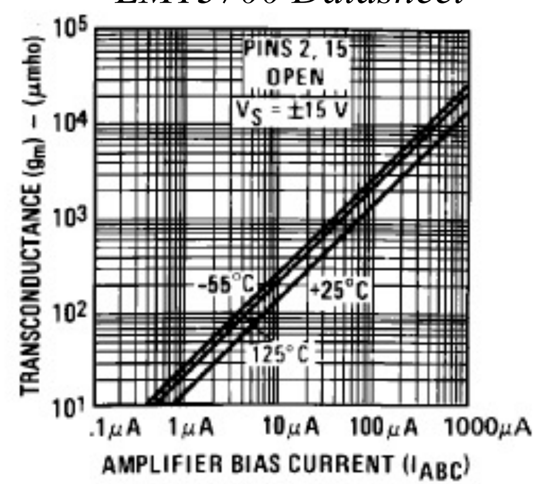




MTU ECE Diff Amp Notes

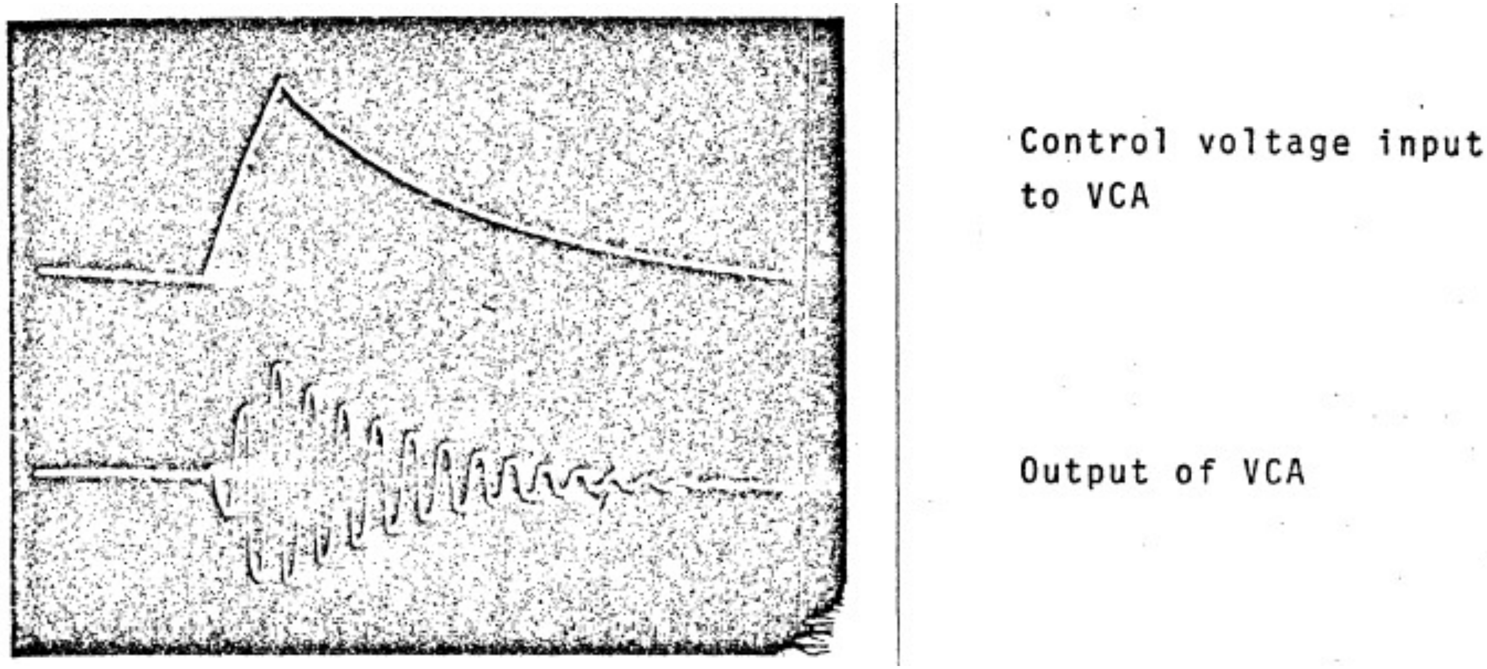
Increasing $+V_{IN}$ increases i_{c1}, which decreases i_{c2} (for fixed $-V_{IN}$) since the sum of i_{c1} and i_{c2} must equal i_{cTOT}

LM13700 Datasheet



i_{cTOT} is proportional to i_{CTL}, and the voltage across the collector resistors is proportional to i_{cTOT}, hence the gain of this circuit is set by i_{cTOT}

Voltage Controlled Amplifiers



VCA output for sinusoidal input and given control voltage

$$V_{out} = V_{in} * V_{ctl} \text{ (or 0 if } V_{ctl} < 0)$$

Voltage-Controlled Amplifiers (VCA)

Burr-Brown Products from Texas Instruments

VCA610

www.ti.com

WIDEBAND VOLTAGE CONTROLLED AMPLIFIER

FEATURES

- WIDE GAIN CONTROL RANGE: 77dB
- SMALL PACKAGE: SO-8
- WIDE SIGNAL BANDWIDTH: 30MHz
- LOW VOLTAGE NOISE: 2.2nV/√Hz
- FAST GAIN SLEW RATE: 300dB/μs

APPLICATIONS

- OPTICAL DISTANCE MEASUREMENT
- AGC AMPLIFIERS
- ULTRASOUND
- SONAR
- ACTIVE FILTERS
- LOG AMPLIFIERS
- IF CIRCUITS
- CCD CAMERAS

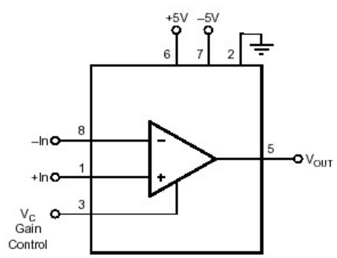
DESCRIPTION

The VCA610 is a wideband, continuously variable, voltage-controlled gain amplifier. It provides linear-dB gain control with high impedance inputs. It is designed to be used as a flexible gain-control element in a variety of electronic systems.

The VCA610 has a gain-control range of 77dB (–38.5dB to +38.5dB) providing both gain and attenuation for maximum flexibility in a small SO-8. The broad attenuation range can be used for gradual or controlled channel turn-on and turn-off for applications in which abrupt gain changes can create artifacts or other errors. In addition, the output can be disabled to provide –77dB of attenuation. Group delay variation with gain is typically less than ±2ns across a bandwidth of 1MHz to 15MHz.

The VCA610 has a noise figure of 3.5dB (with an R_S of 200Ω) including the effects of both current and voltage noise. Instantaneous output dynamic range is 70dB for gains of 0dB to +38.5dB with 1MHz noise bandwidth. The output is capable of driving 100Ω. The high-speed, 300dB/μs, gain-control signal is a unipolar (0V to –2V) voltage that varies the gain linearly in dB/V over a –38.5dB to +38.5dB range.

The VCA610 is designed with a very fast overload recovery time of only 200ns. This allows a large signal transient to overload the output at high gain, without obscuring the low-level signals following closely behind. The excellent overload recovery time and distortion specifications optimize this device for low-level doppler measurements.



TEXAS INSTRUMENTS

ANALOG DEVICES

Dual, Low Noise, Wideband Variable Gain Amplifiers

Also AD603 AD600/AD602*

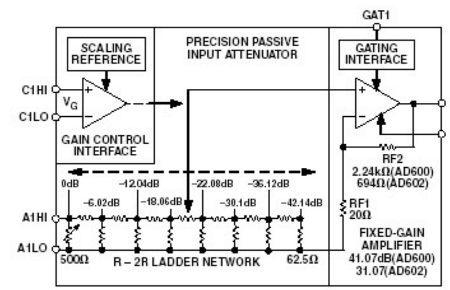
FEATURES

Two Channels with Independent Gain Control
"Linear in dB" Gain Response
Two Gain Ranges:
AD600: 0 dB to 40 dB
AD602: –10 dB to +30 dB
Accurate Absolute Gain: ±0.3 dB
Low Input Noise: 1.4 nV/√Hz
Low Distortion: –60 dBc THD at ±1 V Output
High Bandwidth: DC to 35 MHz (–3 dB)
Stable Group Delay: ±2 ns
Low Power: 125 mW (Max) per Amplifier
Signal Gating Function for Each Amplifier
Drives High-Speed A/D Converters
MIL-STD-883-Compliant and DESC Versions Available

APPLICATIONS

Ultrasound and Sonar Time-Gain Control
High-Performance Audio and RF AGC Systems
Signal Measurement

FUNCTIONAL BLOCK DIAGRAM



PRODUCT DESCRIPTION

The AD600 and AD602 dual channel, low noise variable gain amplifiers are optimized for use in ultrasound imaging systems, but are applicable to any application requiring very precise gain, low noise and distortion, and wide bandwidth. Each independent channel provides a gain of 0 dB to +40 dB in the AD600 and –10 dB to +30 dB in the AD602. The lower gain of the AD602 results in an improved signal-to-noise ratio at the output. However, both products have the same 1.4 nV/√Hz input noise spectral density. The decibel gain is directly proportional to the control voltage, is accurately calibrated, and is supply- and temperature-stable.

To achieve the difficult performance objectives, a proprietary circuit form—the X-AMP®—has been developed. Each channel of the X-AMP comprises a variable attenuator of 0 dB to –42.14 dB followed by a high speed fixed gain amplifier. In this way, the amplifier never has to cope with large inputs, and can benefit from the use of negative feedback to precisely define the gain and dynamics. The attenuator is realized as a seven-stage R-2R ladder network having an input resistance of 100 Ω, laser-trimmed to ±2%. The attenuation between tap points is 6.02 dB; the gain-control circuit provides continuous interpolation between these taps. The resulting control function is linear in dB.

The gain-control interfaces are fully differential, providing an input resistance of ~15 MΩ and a scale factor of 32 dB/V (that is, 31.25 mV/dB) defined by an internal voltage reference. The response time of this interface is less than 1 μs. Each channel also has an independent gating facility that optionally blocks signal transmission and sets the dc output level to within a few millivolts of the output ground. The gating control input is TTL and CMOS compatible.

The maximum gain of the AD600 is 41.07 dB, and that of the AD602 is 31.07 dB; the –3 dB bandwidth of both models is nominally 35 MHz, essentially independent of the gain. The signal-to-noise ratio (SNR) for a 1 V rms output and a 1 MHz noise bandwidth is typically 76 dB for the AD600 and 86 dB for the AD602. The amplitude response is flat within ±0.5 dB from 100 kHz to 10 MHz; over this frequency range the group delay varies by less than ±2 ns at all gain settings.

Each amplifier channel can drive 100 Ω load impedances with low distortion. For example, the peak specified output is ±2.5 V minimum into a 500 Ω load, or ±1 V into a 100 Ω load. For a 200 Ω load in shunt with 5 pF, the total harmonic distortion for a ±1 V sinusoidal output at 10 MHz is typically –60 dBc.

The AD600J and AD602J are specified for operation from 0°C to 70°C, and are available in both 16-lead plastic DIP (N) and 16-lead SOIC (R). The AD600A and AD602A are specified for operation from –40°C to +85°C and are available in both 16-lead cerdip (Q) and 16-lead SOIC (R).

The AD600S and AD602S are specified for operation from –55°C to +125°C and are available in a 16-lead cerdip (Q) package and are MIL-STD-883 compliant. The AD600S and AD602S are also available under DESC SMD 5962-94572.

OTA's (LM3080, LM13700)

National Semiconductor

February 1995

LM3080
Operational Transconductance Amplifier

General Description

The LM3080 is a programmable transconductance block intended to fulfill a wide variety of variable gain applications. The LM3080 has differential inputs and high impedance push-pull outputs. The device has high input impedance and its transconductance (g_m) is directly proportional to the amplifier bias current (I_{ABC}).

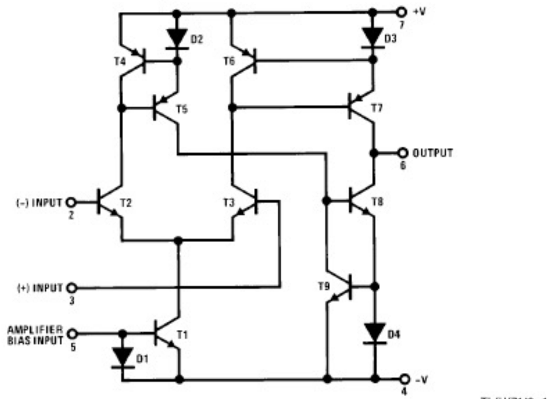
High slew rate together with programmable gain make the LM3080 an ideal choice for variable gain applications such as sample and hold, multiplexing, filtering, and multiplying.

The LM3080N and LM3080AN are guaranteed from 0°C to +70°C.

Features

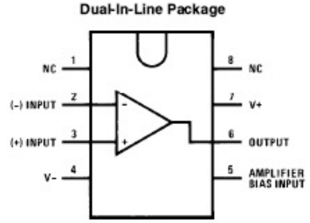
- Slew rate (unity gain compensated): 50 V/μs
- Fully adjustable gain: 0 to $g_m \bullet R_L$ limit
- Extended g_m linearity: 3 decades
- Flexible supply voltage range: ±2V to ±18V
- Adjustable power consumption

Schematic and Connection Diagrams



TL/H/7148–1

Dual-In-Line Package



TL/H/7148–2

Current Output

Need Transimpedance Amp

Top View

Order Number LM3080AN, LM3080M or LM3080N
See NS Package Number M08A or N08E

RRD-B30M115/Printed in U. S. A.

National Semiconductor

LM13700
Dual Operational Transconductance Amplifiers with Linearizing Diodes and Buffers

General Description

The LM13700 series consists of two current controlled transconductance amplifiers, each with differential inputs and a push-pull output. The two amplifiers share common supplies but otherwise operate independently. Linearizing diodes are provided at the inputs to reduce distortion and allow higher input levels. The result is a 10 dB signal-to-noise improvement referenced to 0.5 percent THD. High impedance buffers are provided which are especially designed to complement the dynamic range of the amplifiers. The output buffers of the LM13700 differ from those of the LM13600 in that their input bias currents (and hence their output DC levels) are independent of I_{ABC}. This may result in performance superior to that of the LM13600 in audio applications.

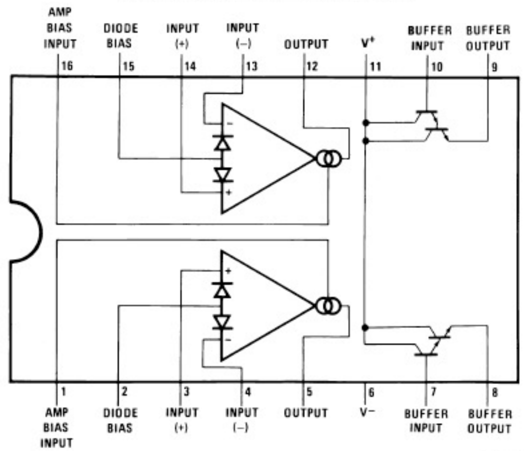
Features

- g_m adjustable over 6 decades
- Excellent g_m linearity
- Excellent matching between amplifiers
- Linearizing diodes
- High impedance buffers
- High output signal-to-noise ratio

Applications

- Current-controlled amplifiers
- Current-controlled impedances
- Current-controlled filters
- Current-controlled oscillators
- Multiplexers
- Timers
- Sample-and-hold circuits

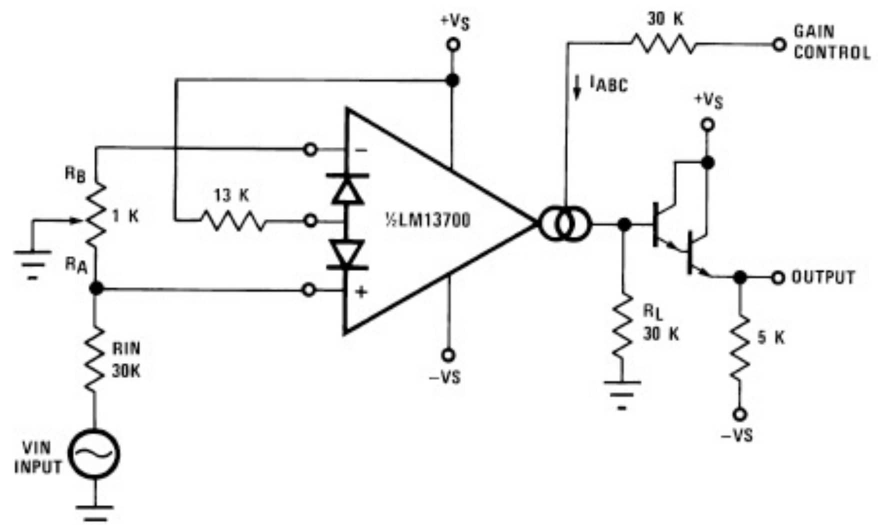
Dual-In-Line and Small Outline Packages



00798102

Top View

Order Number LM13700M, LM13700MX or LM13700N
See NS Package Number M16A or N16A



VCA Arrays

ANALOG DEVICES

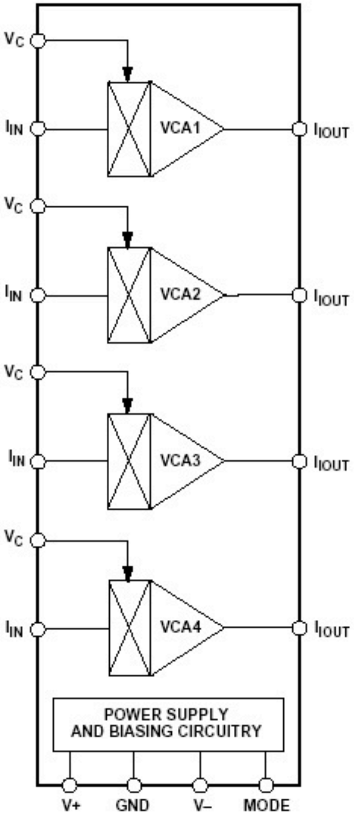
Low Cost Quad Voltage Controlled Amplifier

SSM2164

FEATURES
Four High Performance VCAs in a Single Package
0.02% THD
No External Trimming
120 dB Gain Range
0.07 dB Gain Matching (Unity Gain)
Class A or AB Operation

APPLICATIONS
Remote, Automatic, or Computer Volume Controls
Automotive Volume/Balance/Faders
Audio Mixers
Compressor/Limiters/Compandors
Noise Reduction Systems
Automatic Gain Controls
Voltage Controlled Filters
Spatial Sound Processors
Effects Processors

FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

The SSM2164 contains four independent voltage controlled amplifiers (VCAs) in a single package. High performance (100 dB dynamic range, 0.02% THD) is provided at a very low cost-per-VCA, resulting in excellent value for cost sensitive gain control applications. Each VCA offers current input and output for maximum design flexibility, and a ground referenced –33 mV/dB control port.

All channels are closely matched to within 0.07 dB at unity gain, and 0.24 dB at 40 dB of attenuation. A 120 dB gain range is possible.

A single resistor tailors operation between full Class A and AB modes. The pinout allows upgrading of SSM2024 designs with minimal additional circuitry.

The SSM2164 will operate over a wide supply voltage range of ±4 V to ±18 V. Available in 16-pin P-DIP and SOIC packages, the device is guaranteed for operation over the extended industrial temperature range of –40°C to +85°C.

Analog Multipliers (4-Quadrant)

ANALOG DEVICES

Low Cost Analog Multiplier

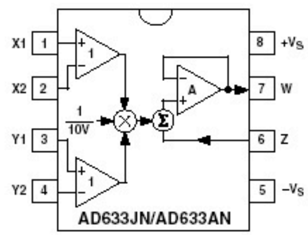
AD633

FEATURES
- 4-Quadrant Multiplication
- Low Cost 8-Lead Package
- Complete—No External Components Required
- Laser-Trimmed Accuracy and Stability
- Total Error within 2% of FS
- Differential High Impedance X and Y Inputs
- High Impedance Unity-Gain Summing Input
- Laser-Trimmed 10 V Scaling Reference

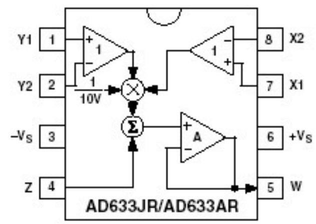
APPLICATIONS
- Multiplication, Division, Squaring
- Modulation/Demodulation, Phase Detection
- Voltage Controlled Amplifiers/Attenuators/Filters

CONNECTION DIAGRAMS

8-Lead Plastic DIP (N) Package



8-Lead Plastic SOIC (RN-8) Package



$$W = \frac{(X_1 - X_2)(Y_1 - Y_2)}{10V} + Z$$

PRODUCT DESCRIPTION

The AD633 is a functionally complete, four-quadrant, analog multiplier. It includes high impedance, differential X and Y inputs and a high impedance summing input (Z). The low impedance output voltage is a nominal 10 V full scale provided by a buried Zener. The AD633 is the first product to offer these features in modestly priced 8-lead plastic DIP and SOIC packages.

The AD633 is laser calibrated to a guaranteed total accuracy of 2% of full scale. Nonlinearity for the Y input is typically less than 0.1% and noise referred to the output is typically less than 100 μV rms in a 10 Hz to 10 kHz bandwidth. A 1 MHz bandwidth, 20 V/μs slew rate, and the ability to drive capacitive loads make the AD633 useful in a wide variety of applications where simplicity and cost are key concerns.

The AD633's versatility is not compromised by its simplicity. The Z-input provides access to the output buffer amplifier, enabling the user to sum the outputs of two or more multipliers, increase the multiplier gain, convert the output voltage to a current, and configure a variety of applications.

The AD633 is available in an 8-lead plastic DIP package (N) and 8-lead SOIC (R). It is specified to operate over the 0°C to 70°C commercial temperature range (J Grade) or the –40°C to +85°C industrial temperature range (A Grade).

PRODUCT HIGHLIGHTS

1. The AD633 is a complete four-quadrant multiplier offered in low cost 8-lead plastic packages. The result is a product that is cost effective and easy to apply.
2. No external components or expensive user calibration are required to apply the AD633.
3. Monolithic construction and laser calibration make the device stable and reliable.
4. High (10 MΩ) input resistances make signal source loading negligible.
5. Power supply voltages can range from ±8 V to ±18 V. The internal scaling voltage is generated by a stable Zener diode; multiplier accuracy is essentially supply insensitive.

4 Quadrant means: Multiplying by negative values (negative voltages) inverts the output. Either input can go negative.

VCA's are 2 Quadrant devices – the control input can't go negative, although the signal input can.