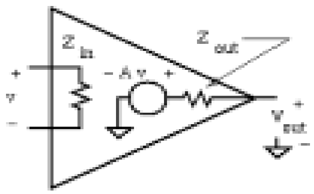
6.111 Lecture # 15

Operational Amplifiers

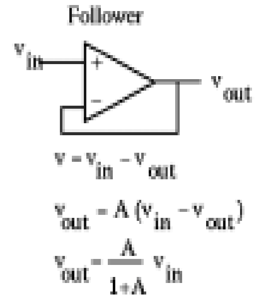
Parameter		Ideal	'741	'357
Int Gain	A	Infinity	200,000/f(Hz)	20x10^6/f(Hz)
Output Impedance	Zout	0	~75 Ohms	
Input Impedance	Zin	Infinity	~300 kOhms	~10^12 Ohms

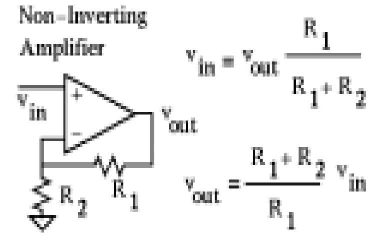


Uses of Op Amps

Analog uses employ negative feedback to drive + input to (nearly) the same potential as the - input

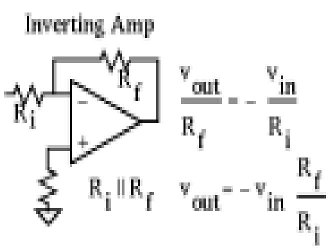
Follower and Non-Inverting Amplifier Circuits:

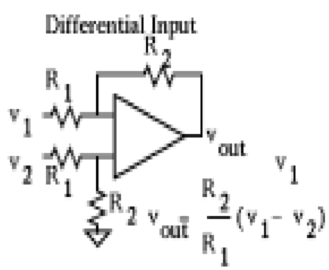




More Analog Circuits

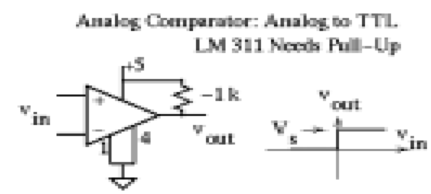
Inverting Amplifier and Differential Input Amplifier

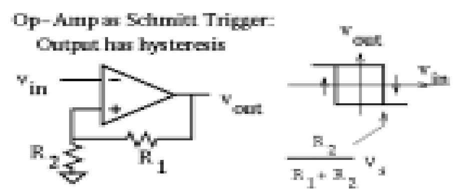




Positive Feedback

Analog Comparator
Is V+ > V- ?
Output is a DIGITAL signal
Schmitt Trigger squares up signals





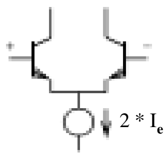
Bias Currents

Many Op-Amps have bipolar inputs

Emitter coupled transistor pair

High differential gain

But sum of input currents = I_e/β



Many Op-Amps have FET inputs

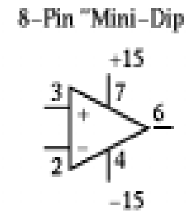
Bias currents are very small

Pinouts: 8-pin "mini-dip"

Common packaging

Pin 3	**Positive Input**
Pin 2	**Negative Input**
Pin 6	**Output**
Pin 7	**Positive Supply**
Pin 4	**Negative Supply**

You may need these pinouts:



Slew Rate

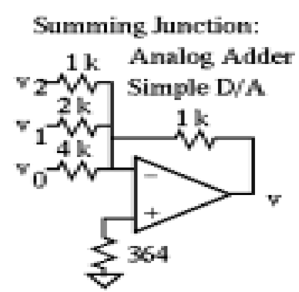
Is related to frequency response

Summing Junction

If V+ is at zero potential, so is V- (assuming negative feedback)

Output voltage is proportional to sum of currents

Currents are inversely proportional to resistances, IF voltages are the same

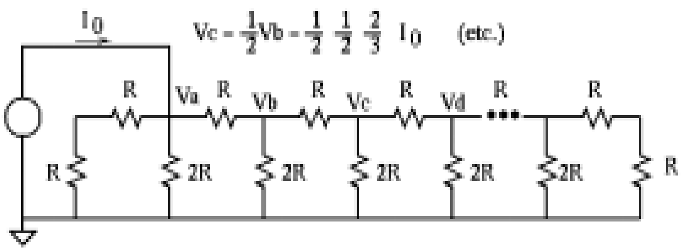


Useful Circuit

Digital To Analog Converters: Use R – 2R Ladder
Driving Point Impedance is 2/3 R
Voltage Divider Ratio, Node–Node is 1/2

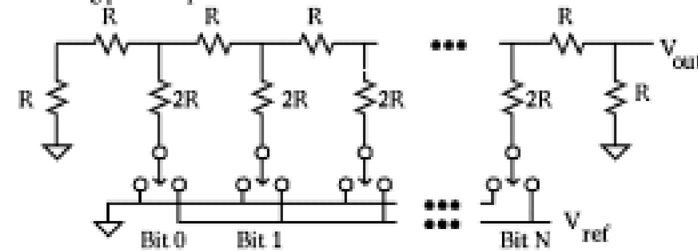
$Va = \frac{2}{3} I_0 \qquad Vb = \frac{1}{2} Va = \frac{1}{2}\frac{2}{3} I_0$

$Vc = \frac{1}{2} Vb = \frac{1}{2}\frac{1}{2}\frac{2}{3} I_0$ (etc.)



How to build a D/A

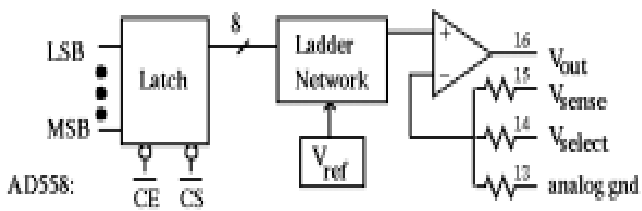
Real D/A Converters use a voltage reference and switches Note that since driving point impedance is the same for each cell:



$V_{out} = \frac{1}{6} V_{ref} [B_7 + \frac{1}{2} B_6 + \frac{1}{4} B_5 + ... + \frac{1}{128} B_0]$

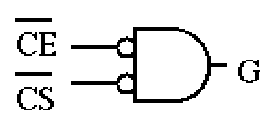
AD 558

8-Bit D/A Converter
You will use in Lab 3



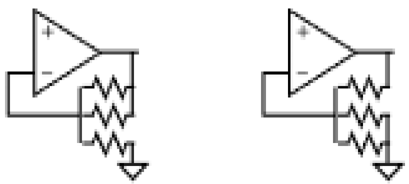
Control of AD 558

Is relatively simple
Remember -- This is a LATCH
Data goes through to analog when G is HIGH
Ouput can be very noisy when bits are settling
(particularly if the source is something like memory)



Output of AD 558

Much like a Non-Inverting Operational Amplifier
Left circuit goes 0 to 2.5 volts
Right circuit goes 0 to 10 volts
- **Needs 12 volt power supply!**



Analog to Digital Conversion

Harder than Digital to Analog

Several Different Methods are Used: (here are three)

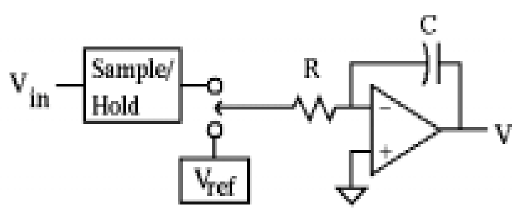
Dual Slope Integration
- **Uses time which can be measured accurately**
- **Typically very accurate but slow**
- **Not widely used any more**

Multiple Conversions (FLASH)
- **Very fast**
- **Used for converting TV signals**
- **Difficult to make in high precision**
- **AD 775**

Successive Approximation
- **Medium speed**
- **Can be economical**
- **AD 670**

Dual Slope

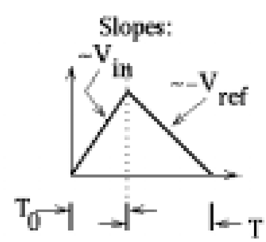
Dual Slope Integrating A/D
- **Accurate but slow**
- **Requires accurate integrator**
- **And accurate counter and clock**



Operation of Dual Slope

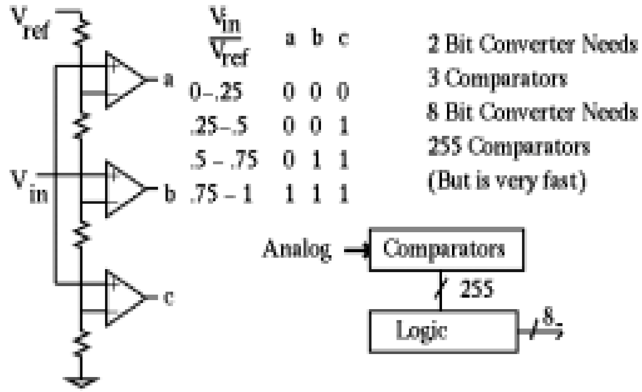
First, Counts
- **for known time**
- **with input voltage at input to the integrator**

Then counts
- **with reference voltage at input**
- **and measures time**

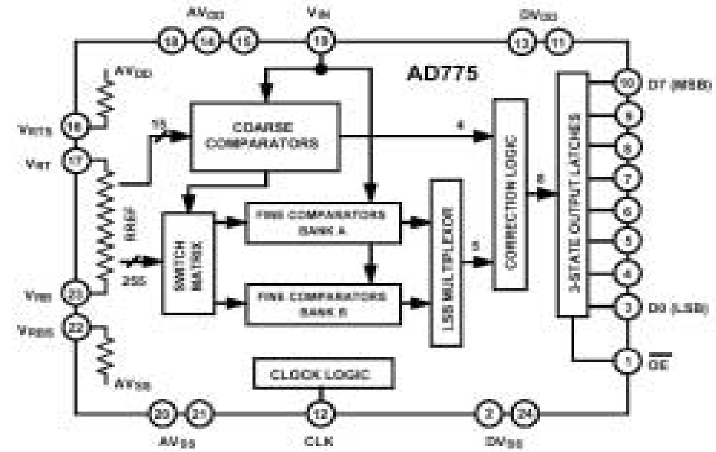


$$T/T_0 = V_{in} / V_{ref}$$

Flash Converter



AD 775 Functional Block Diagram

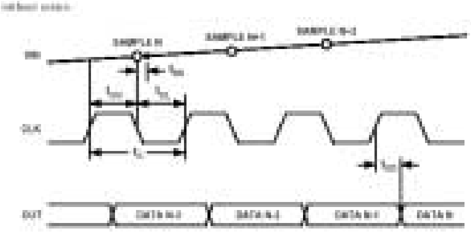


AD 775 Timing: Samples on falling edge, data available on rising edge, 2 1/2 clock cycles later.

TIMING SPECIFICATIONS

	Symbol	Min	Typ	Max	Units
Maximum Conversion Rate		20	35		MHz
Clock Period	t_C	50			ns
Clock High	t_{CH}	25			ns
Clock Low	t_{CL}	25			ns
Output Delay	t_{OD}		18	30	ns
Pipeline Delay (Latency)				2.5	Clock Cycles
Sampling Delay	t_{SD}		4		ns
Aperture Jitter			30		ps

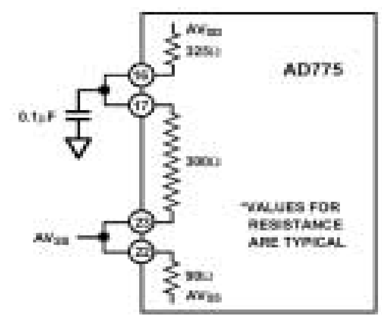
Specifications subject to change without notice.



Voltage Reference

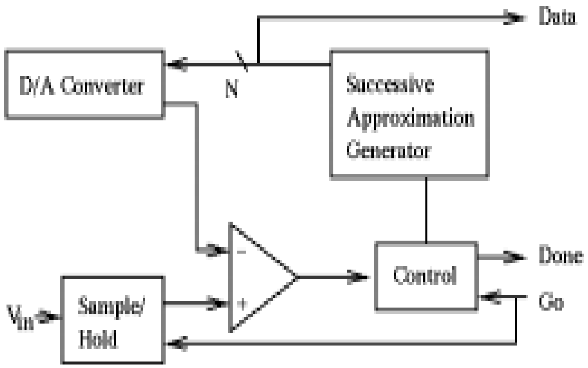
Similar to other flash converters
Needs a stable reference voltage
Can handle different Ranges of voltage defined by top and bottom of ladder

Caution is required: the ladder is fragile!
- **Voltage range < 2.8 volts**
- **Linearity suffers if < 1.8 volts**
- **AV means "Analog Voltage" (supply)**
- **If you use this converter, get AV_{DD} set BEFORE connecting to the A/D converter**



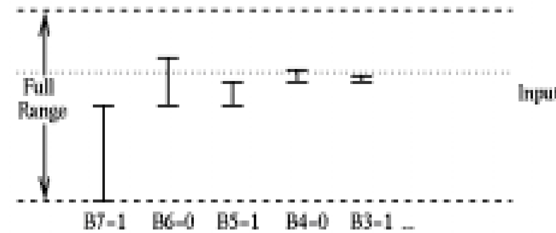
Successive Approximation A/D

Widely used in low and medium frequency applications (such as audio)



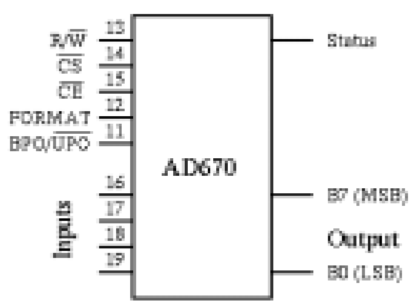
Operation of Successive Approximation A/D

- **Set one bit at a time**
- **D/A generates analog voltage**
- **Compare with input**
- **If overshot, turn that bit on**
- **Finishes in fixed time**

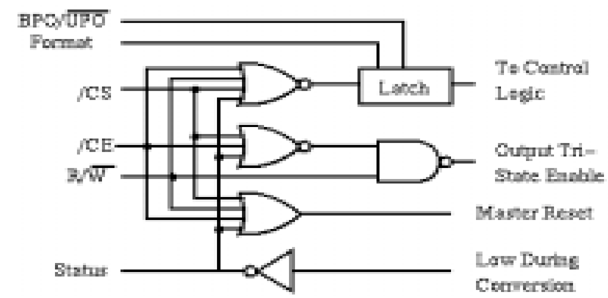


AD 670

- **Conversion time 10 microseconds**
- **Internal voltage reference**
- **Multiple input ranges**
- **Two output formats**



Control Logic for AD 670



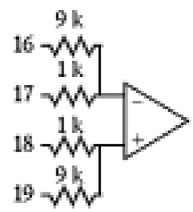
Mode Control:

BPO/UPO	Format	Input Range	Output
0	0	Unipolar	Binary (unsigned)
1	0	Bipolar	Binary (unsigned but offset)
0	1	Unipolar	2's Complement
1	1	Bipolar	2's Complement

AD 670 Can Handle Multiple Input Ranges

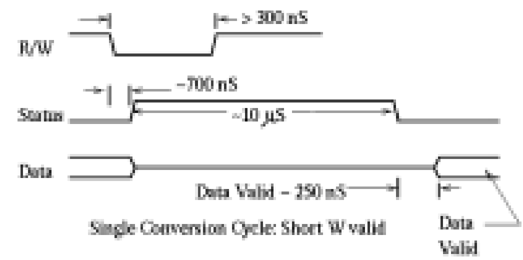
High Input Voltage Range
- 0 to 2.55 V or
- -1.28 to +1.28 V
- Strap Pins 17 and 18 to GND
- Input is Pins 16 (+) and 19 (-)

Low Input Voltage Range
- 0 to 255 mV or
- -128 to +128 mV
- Strap Pins 16 to 17 (+)
- and 18 to 19 (-)



Timing: Single Conversion Cycle

Assumes /CS and /CE are LOW
Need to control these if connected to a bus!
Conversion initiated by R/W LOW pulse

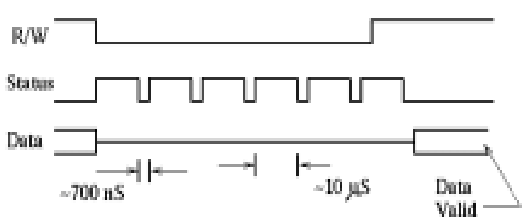


Single Conversion Cycle: Short W valid

Timing: Multiple Conversion Cycles

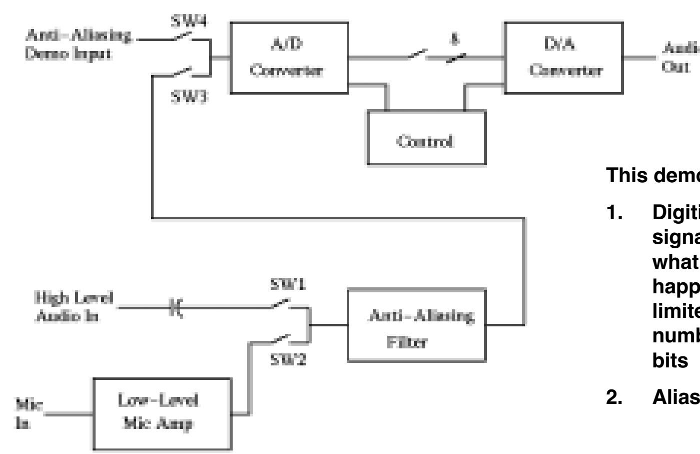
Here is what happens if you hold R/W low

Must wait for last conversion to finish



Multiple Conversion Cycles: Must wait for last to finish

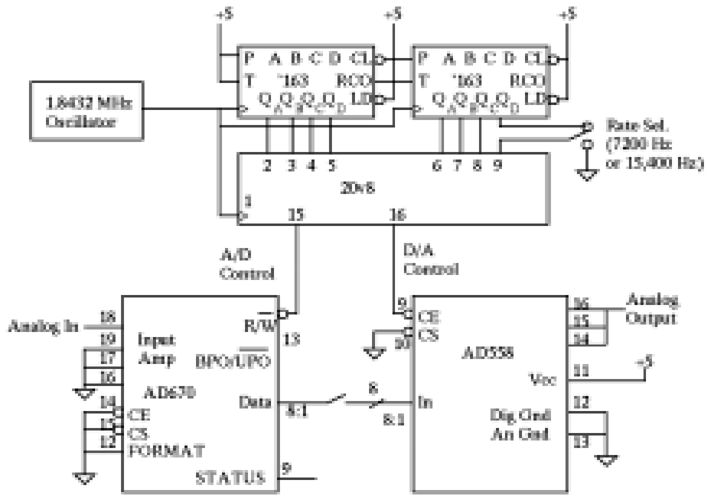
A/D, D/A and Aliasing Demo



This demo shows:

1. Digitized signals (and what happens with limited number of bits
2. Aliasing

Control and Digital Section



Analog: Gain and Anti-Aliasing