(14.1) (a) Show that the circuits in Figures 14.1 and 14.2 differentiate, integrate, sum, and difference.

Zin and Zout share current I

The virtual ground is held constant

$$I_{in} = \frac{V_{in} - 0}{R_{in}} = I_{out}$$

$$V_{out} = 0 + I_{out} R_{out}$$

$$I = \frac{V_{in}}{R_{in}}$$

$$V_C = \int I dt$$

$$V_{out} = 0 = V_C = \int \frac{V_{in}}{R_{in}} dt$$

$$i_{in} = C \frac{dV_C}{dt}$$

$$i = \frac{V_{out}}{R}$$

$$V_{out} = \frac{dV_{in}}{dt} CR$$

$$i_{out} = \sum i_{in} = \sum \frac{V_{in}}{R_{in}}$$

$$V_{out} = i_{out} R_{out} = R_{out} \sum \frac{V_{in}}{R_{in}}$$

$$V_+ = V_2 \left(\frac{R_{out}}{R_{in} + R_{out}} \right)$$

$$V_- = V_{out}\left(\frac{R_{in}}{R_{in}+R_{out}}\right) + V_1\left(\frac{R_{out}}{R_{in}+R_{out}}\right)$$

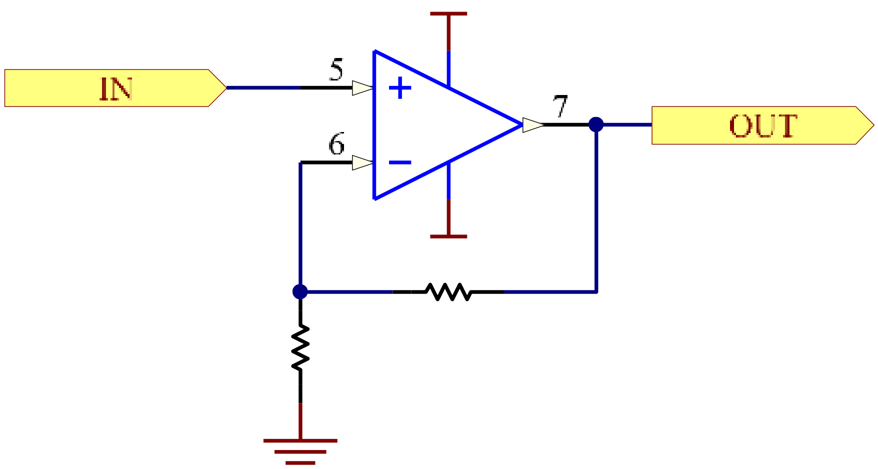
$$V_2\left(\frac{R_{out}}{R_{in}+R_{out}}\right) = V_{out}\left(\frac{R_{in}}{R_{in}+R_{out}}\right) + V_1\left(\frac{R_{out}}{R_{in}+R_{out}}\right)$$

$$V_2 R_{out} = V_{out} R_{in} + V_1 R_{out}$$

$$V_2 R_{out} - V_1 R_{out} = V_{out} R_{in}$$

$$V_{out} = -(V_2 - V_1)\frac{R_{out}}{R_{in}}$$

(b) Design a non-inverting op-amp amplifier. Why are they used less commonly than inverting ones?

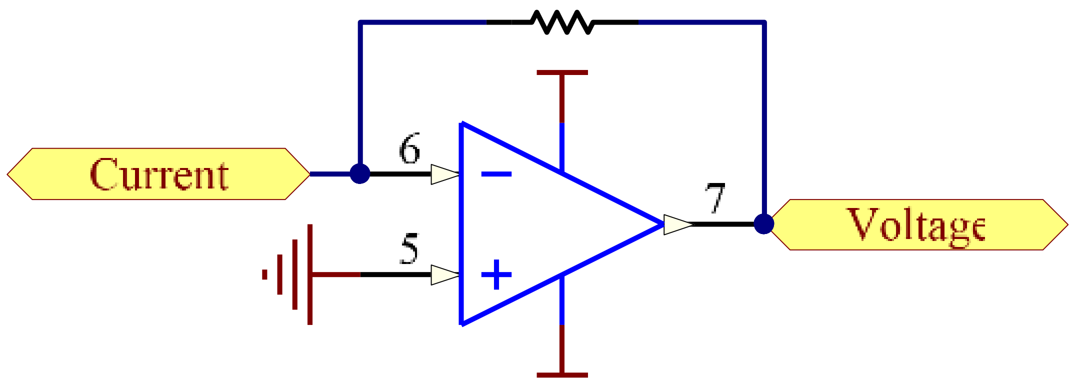


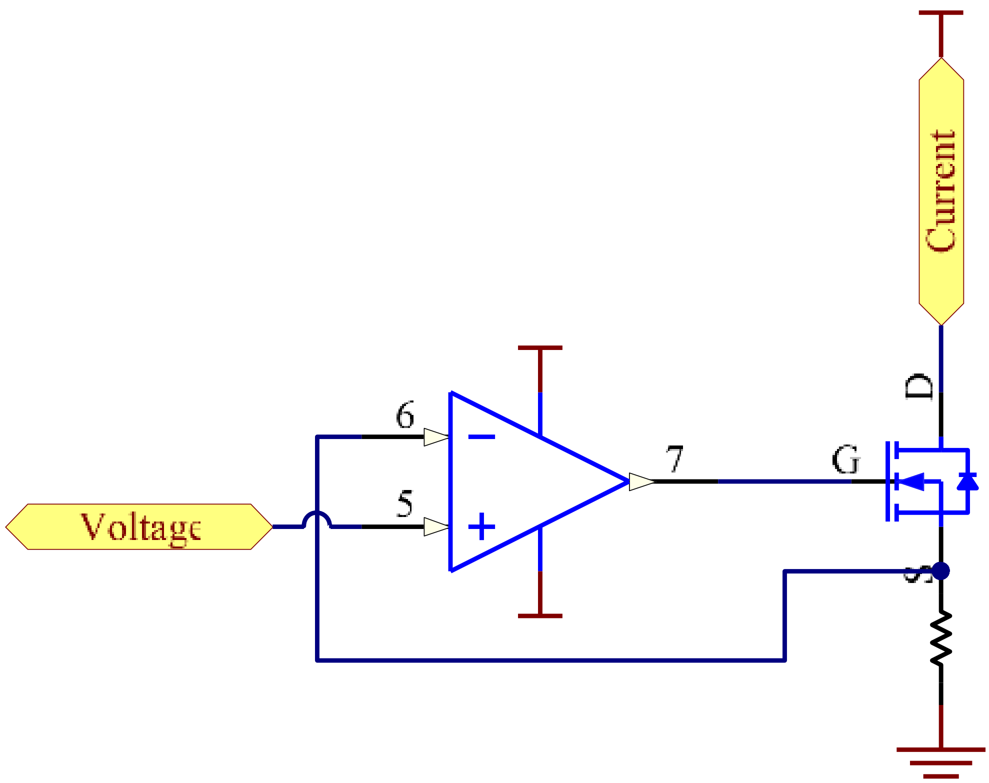
William's Rule: "Always invert (except when you can't)."

"A zero volt summing point is a very friendly and reassuring place. It is (nominally) predictable, mathematically docile, and immune from the sneaky common mode dragons."

CMRR aside, a non-inverting amplifier has higher input impedance, lower output impedance, and doesn't suffer blow-through at frequencies the op-amp can't keep up with.

(c) Design a transimpedance (voltage out proportional to current in) and a transconductance (current out proportional to voltage in) op-amp circuit.





(d) Derive equation (14.16).

$$14.16: \quad \frac{dV_F}{dt} = -\frac{R_O}{R_I}\frac{dV_{PD}}{dt} - \frac{V_{PD}}{R_I C}$$

$$i = \frac{V_{PD}}{R_1}$$

$$V_F = iR_0 + V_C$$

$$\frac{dV_C}{dt} = \frac{i}{C}$$

$$V_F = \frac{V_{PD}}{R_1} R_0 + V_C$$

$$dV_F = dV_{PD}\frac{R_0}{R_1} + dV_C$$

$$dV_F = dV_{PD}\frac{R_0}{R_1} + \frac{i}{C}$$

$$-dV_F = dV_{PD}\frac{R_0}{R_1} + \frac{V_{PD}}{R_1 C}$$

(14.2) If an op-amp with a gain–bandwidth product of 10 MHz and an open-loop DC gain of 100 dB is configured as an inverting amplifier, plot the magnitude and phase of the gain as a function of frequency as Rout/Rin is varied.

(14.3) A lock-in has an oscillator frequency of 100 kHz, a bandpass filter Q of 50 (remember that the Q or quality factor is the ratio of the center frequency to the width between the frequencies at which the power is reduced by a factor of 2), an input detector that has a flat response up to 1 MHz, and an output filter time constant of 1 s. For simplicity, assume that both filters are flat in their passbands and have sharp cutoffs. Estimate the amount of noise reduction at each stage for a signal corrupted by additive uncorrelated white noise.

$$A(t) + \eta(t)$$

$$\big(A(t) + \eta(t)\big)e^{i\omega t}$$

(14.4) (a) For an order 4 maximal LFSR work out the bit sequence.

1 1 1 0 1 0 1 1 0 0 1 0 0 0 1

```
arr = [1,0,0,0]
constants = [1,0,0,1]

for i in range(64):
   output = sum([a*b for a,b in zip(arr, constants)]) % 2
   print output,
   arr = [output]+ arr[:-1]
```

(b) If an LFSR has a chip rate of 1 GHz, how long must it be for the time between repeats to be the age of the universe?

13.772 Byr * 1GHz = $4.34E^{26}$

N=89

(c) Assuming a flat noise power spectrum, what is the coding gain if the entire sequence is used to send one bit?

Coding gain is 10log10(2^89)

A linear block code's coding gain is KD/N:

Maximum distance code d = n-k+1

$$k(n-k+1)/n = k - k/n - 1/n$$

(14.5) What is the SNR due to quantization noise in an 8-bit A/D? 16-bit? How much must the former be averaged to match the latter?

Quantization error is ½ an LSB on average flatly distributed. The energy is therefore:

$$\int_{-2^{-N-1}}^{2^{-N-1}} x dx =$$

$$\sqrt{\int_{-\frac{q}{2}}^{\frac{q}{2}} e^2} = \sqrt{\int_{-2^{-N-1}}^{2^{-N-1}} x^2/2^{N+1}} = \sqrt{\frac{1}{12} 2^{-2(N+1)}}$$

Quantization noise $= 2^{-(N+1)}\sqrt{\frac{1}{12}}$

Signal Power = rms of a full scale sinusoid = $\frac{1}{4\sqrt{2}}$

Snr = $\frac{(1/4\sqrt{2})}{2^{-(N+1)}/\sqrt{12}}$

8 bit= .00056 → -65dB

16 bit = 0.0000022 → -113dB

Oversampling 8 additional bits requires $2^8 = 256$ samples, but would never work in practice.

(14.6) The message 00 10 01 11 00 (c1, c2) was received from a noisy channel. If it was sent by the convolutional encoder in Figure 14.20, what data were transmitted?

I wrote a naïve decoder. Message 10110 should result in 00 1**1** 01 **0**1 00, which is only two errors.

```
compare =[0,0,1,0,0,1,1,1,0,0]

possiblecodes = range(32)
for code in possiblecodes:
    arr = [0,0,0]
    val = []
    print code
    for i in range(5):
        inbit = 1&(code>>i)
        arr = [inbit, arr[0], arr[1]]

        c1=sum(arr)%2
        c2=(arr[0]+arr[2])%2
        print c1,c2,' ',
        val.append(c1)
```

```
    val.append(c2);
print ''
right= [i[0]==i[1] for i in zip(val,compare)]
print right
print sum([i*1 for i in right])
print
```