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PIT 2022

PSET 12

15.1

a.

By Kirchhoff's Law for current, we know that the sum of all the current entering a junction is zero. As always we have Ohm's law: $V = IR$ and "Ohm's law" for capacitors: $I = C\frac{dV}{dt}$. We apply these for each of the following scenarios

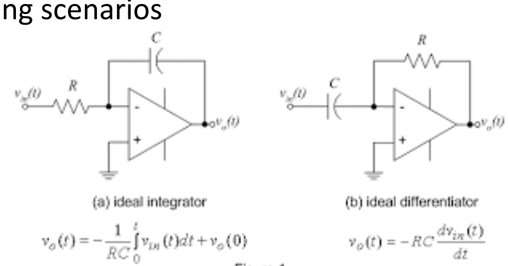


Figure 1

Image source: http://www.ee.nmt.edu/~wedeward/EE212L/SP04/lab09.html

Differentiator:

$$\frac{dV_{in}}{dt}C + \frac{V_{out}}{R} = 0$$
$$V_{out} = -RC\frac{dV_{in}}{dt}$$

Integrator:

$$\frac{dV_{out}}{dt}C + \frac{V_{in}}{R} = 0$$
$$V_{out} = \int \frac{V_{in}}{RC}dt$$

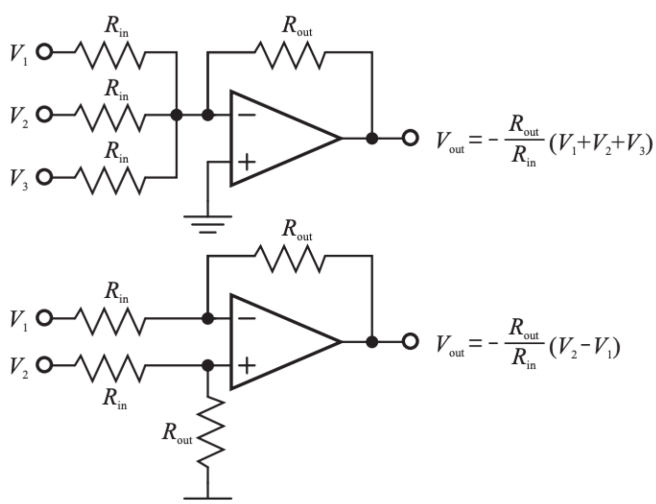


Image from text.

Summing:

$$\frac{V_1}{R_{in}} + \frac{V_2}{R_{in}} + \cdots \frac{V_n}{R_{in}} + \frac{V_{out}}{R_{out}} = 0$$

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

Differential:

We know that the voltage across the two inputs should be the same, i.e.:

$$\frac{V_2 - V_+}{R_{in}} = \frac{V_+}{R_{out}}$$

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

And $V_+ = V_-$.

$$\frac{R_{out}V_2}{R_{in} + R_{out}} = V_+$$

Then:

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

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

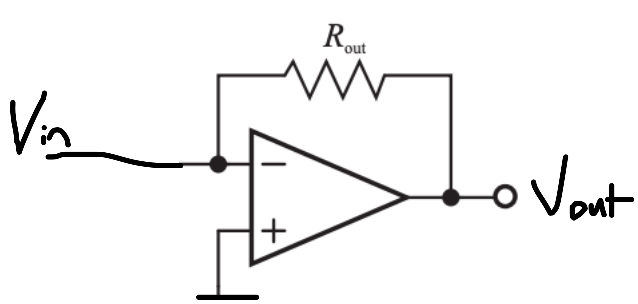
$$\frac{V_1}{R_{in}} - \frac{V_2}{R_{in}} = -\frac{V_{out}}{R_{out}}$$

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

b.

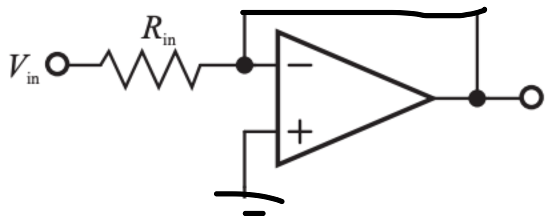
c.

Transimpedance:



Then, $I_{in} + \frac{V_{out}}{R_{out}} = 0$, or $V_{out} = -R_{out}I_{in}$

Transconductance:



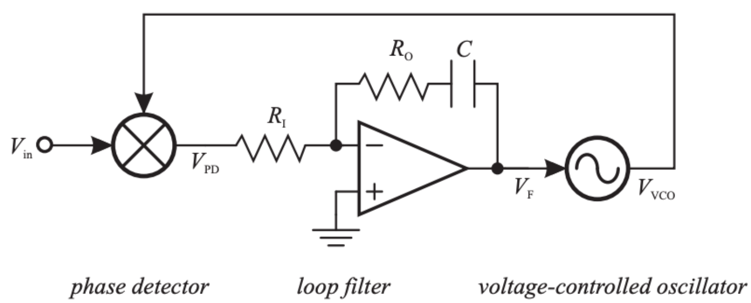
Then, $\frac{V_{in}}{R_{in}} + I_{out} = 0$, or: $I_{out} = -\frac{V_{in}}{R_{in}}$

d.

We are to derive:

$$\frac{dV_f}{dt} = -\frac{R_O}{R_I}\frac{dV_{PD}}{dt} - \frac{V_{PD}}{R_I C}$$

By balancing currents into the non-inverting node of 15.9, shown below.



$$\frac{V_{PD}}{R_I} +$$

15.2

See code.

15.3

Lock-in frequency: 100kHz
Bandpass filter Q: 50 (ratio of center frequency to the distance at which power is reduced by factor of 2)
Input detector: flat response up to 1MHz
Output filter time constant: 1s

We will estimate the noise reduction at each stage for a signal corrupted by additive white noise.

15.4

a.

We are given that an order N Linear Feedback Shift Register (LFSR) satisfies the recursion relation:

$$x_n = \sum_{i=1}^{N} a_i x_{i-1} \ mod(2)$$

The text further gives us that for order 4 maximal LSFR, the i values for which $a_i = 1$ (and not 0) are 1 and 4. So:

$$x_4 = a_1 x_0 + a_2 x_1 + a_3 x_2 + a_4 x_3 = x_0 + x_3$$

Or:

$$x_n = x_{n-4} + x_{n-1}$$

According to Google, a maximal LFSR will cycle through all its possible states, of which it has $2^N - 1$, or 15.

Step	X(n)	X(n-1) (a=1)	X(n-2) (a=0)	X(n-3) (a=0)	X(n-4) (a=1)
1	0	1	1	1	1
2	1	0	1	1	1
3	0	1	0	1	1
4	1	0	1	0	1
5	1	1	0	1	0
6	0	1	1	0	1
7	0	0	1	1	0
8	1	0	0	1	1
9	0	1	0	0	1
10	0	0	1	0	0
11	0	0	0	1	0
12	1	0	0	0	1
13	1	1	0	0	0
14	1	1	1	0	0
15	1	1	1	1	0

b.

Chip rate: 1GHz.

Age of the universe: 13.8*10^9 years, 1 year is 3.15*10^8 seconds, so the universe is 43*10^17s.

So this comes out to this many steps:

$$1 * 10^9 \left[\frac{1}{s}\right] * 43 * 10^{17}[s] = 43 * 10^{26}$$
$$2^N = 43 * 10^{26}$$
$$N = 91$$

c.

$$10 * \log_{10} 2^{91} = 273[dB]$$

15.5

For 8-bit:

$$20 \log_{10} 2^8 = 48.2$$

For 16-bit:

$$20 \log_{10} 2^{16} = 96.3$$

15.6

The message 00 10 01 11 00 (c1,c2) was received from a noisy channel, if it was sent by the convolutional coder in 15.20, etc.

Oh no? What is a trellis. I cry.

15.7

See code.