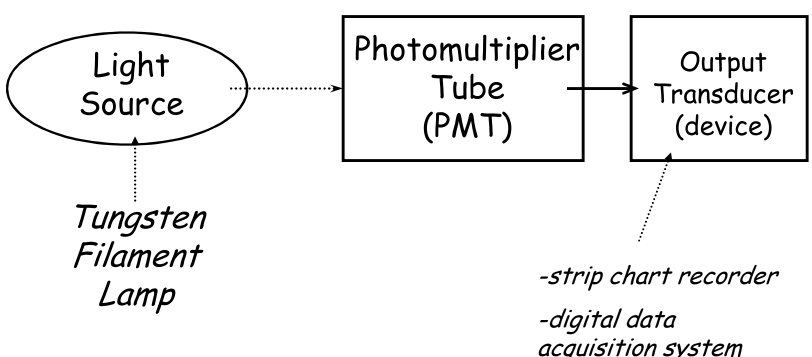
January 25, 2012

- Textbook will be placed on reserve in Library
- Solutions to Prob Set #1 have been posted

1

Hypothetical Instrument

- Let’s explore the signal and noise behavior of a simple light measurement instrument:

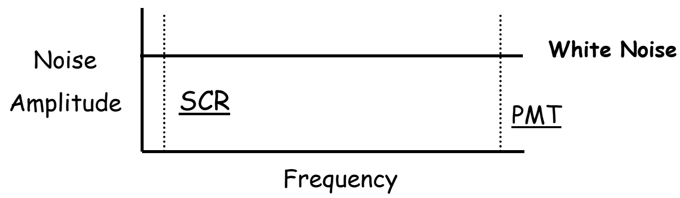


2

Reducing Δf

- Look at *frequency response* of instrument components:

  PMT: 10^7 Hz
  SCR: 10^0 Hz
  DDA: 10^0 - 10^7 Hz (variable)



S/N Enhancement: Impact of Δf

- Output device/transducer limits Δf:

$$\frac{S/N\ (\Delta f = 10^0)}{S/N\ (\Delta f = 10^7)} \approx 10^3$$

- Δf can be easily adjusted using a *low-pass* frequency filter
- BUT: remember that Δf also affects ability to measure the signal (at f_o); $f_o > 0$

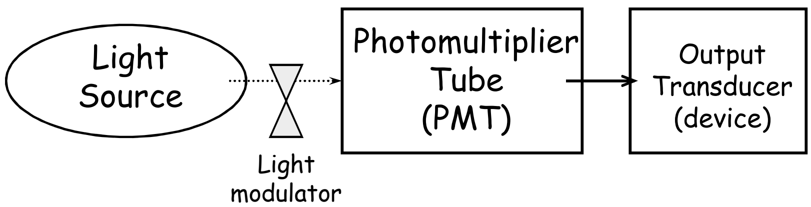
So, object is to keep Δf to a *minimum*,
without reducing the SIGNAL

Reducing 1/f Noise

- We need to *move* f_o to >100 Hz . . . *HOW?*

  → **MODULATE** the source

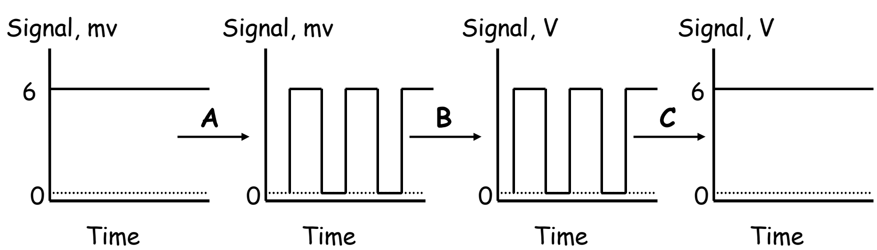
  -analytical signal "encoded" at a freq. where 1/f noise is negligible



5

Tuned Amplification: *Chopper Amplifiers*

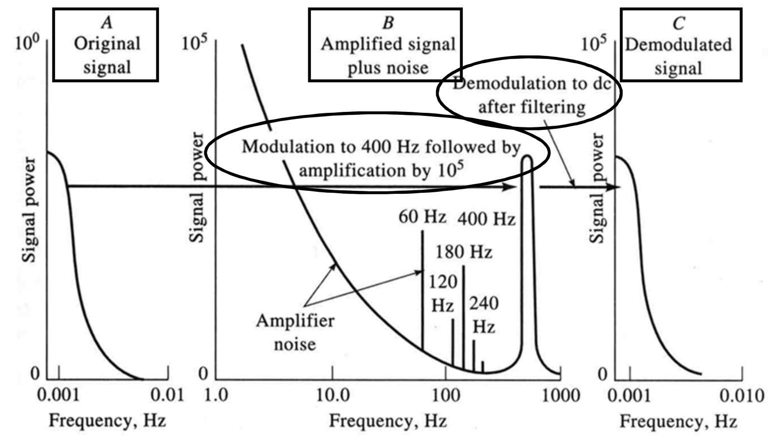
- If we *amplify* the signal **at the modulation frequency**, then we can also *increase the signal* while we *reduce the noise:*



A: *modulate* **B**: *amplify* **C**: *demodulate*

6

Chopper Amplifiers: In the Frequency Domain



7

Lock-In Amplification

- Tuned (chopper) amplification is limited by stability of f_o reference

  -this limits the effective Δf to about 1 Hz

- *Lock-in* amplification tunes the amplifier to *both* f_o as well as the **phase** of the signal

  -results in an effective reduction of Δf to about 0.01 Hz

8

Signal Averaging

- Need a *repeatable* signal (time domain method)
- Sum digitally-stored replicate signals
- How does this improve S/N?

Signal: increases *linearly* with number (n) of replicate signals

Noise: increases as $(n)^{1/2}$

So, **S/N** increases as $\mathbf{(n)^{1/2}}$

9

Signal Averaging: Example

- Suppose we wish to *mass* a **10-mg** object on an analytical balance ($\sigma = 0.1\ mg$)

For a single (n =1) measurement:

S = 10. mg, N = 0.1 mg → **S/N** = ***100***

For n = 4:

S = *n x 10. mg* = 4 x 10. mg = *40. mg*

N = $\sigma_T = (n(\sigma)^2)^{1/2} = (4(0.1)^2)^{1/2} = 2(0.1) =$ *0.2 mg*

S/N = 40./0.2 = ***200***

For n = 16: **S/N** = ***400***

10

Signal Averaging: General

- In general, we can say:

$$(S/N)_n = (n)^{1/2} (S/N)_{n=1}$$

•Diminishing returns:

Suppose, it takes 1 second per measurement?

S/N	n	Time
3	1	1 sec
6	4	4 sec
30	100	100 sec
300	10,000	2.8 ***hours***
3000	1,000,000	11.6 ***days***

11