January 26, 2005

- **No Class: Monday, Jan 31st**
- **Office Hours™**
  - 1:10 – 2:10 pm, Monday, A223 Cook
    - Not next week (no class Monday Jan 31st!)
  - 1-2 pm, Thursday, 300 Waterman
  - 3-4 pm, Friday, 300 Waterman

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More White Noise

- **Shot Noise**

  -current fluctuations due to random motion of e^- across a junction

$$i_{rms} = (2\ i_{avg}\ e\ \Delta f)^{1/2}$$

Average Current — Charge on an electron — Frequency Bandwidth

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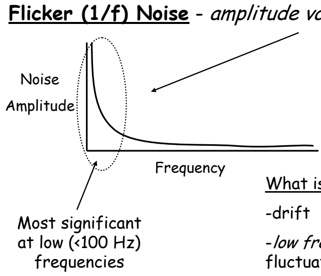
More Noise

2. **Flicker (1/f) Noise** - *amplitude varies with 1/f*



What is it?

-drift

-*low freq.* signal fluctuations

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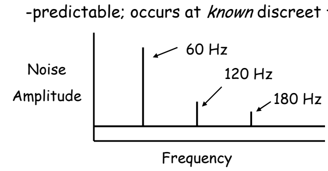
Still More Noise!

3. **Environmental Noise**

   Two types:

   - Interference Noise

     -predictable; occurs at *known* discreet frequencies



Example:

AC "hum" from power-line

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More Environmental Noise

- **Impulse Noise**

  -erratic and unpredictable

  -*difficult to find source*

  -motors

  -solar flares

  -computers

  -temperature variations

  -**difficult to correct!**

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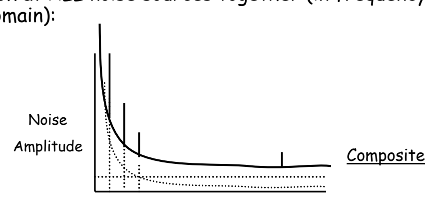
Composite Noise Spectrum

- In order to understand S/N enhancement, need to look at ALL noise sources together (in frequency domain):



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Strategies for Increasing S/N

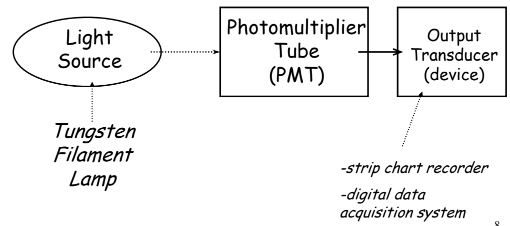
- <u>White Noise:</u> *reduce* Δf, temp, resistance, i_{avg}
- <u>Flicker Noise:</u> *make measurements at frequencies >100 Hz*

BUT:

- <u>Signal:</u> -often at or near dc (low freq.)
  -often directly proportional to resistance
  -often directly proportional to current
  -often measured with transducers having very LARGE Δf

Hypothetical Instrument

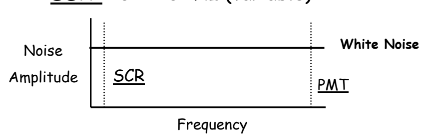
- Let's explore the signal and noise behavior of a simple light measurement instrument:



Reducing Δf

- Look at *frequency response* of instrument components:

  <u>PMT:</u> 10^7 Hz
  <u>SCR:</u> 10^0 Hz
  <u>DDA:</u> 10^0 - 10^7 Hz (variable)



S/N Enhancement: Impact of Δf

- <u>Output device/transducer limts Δf:</u>

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

- Δf can be easily adjusted using a *low-pass* frequency filter
- <u>BUT:</u> 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* $\mathbf{f_o}$ to >100 Hz . . . ***HOW?***

  → **<u>MODULATE</u>** the source
  -analytical signal "encoded" at a freq. where 1/f noise is negligible