Data Acquisition

- Detecting photons by turning them into electrons is only the first step to producing a FITS file.
- A precious few electrons must be turned into a robust voltage and converted to a digital value.

What can go wrong along the way

- addition of noise beyond photon poisson statistics
- introduction of (additional) non-linearity
- unnecessary signal saturation (possibly to user benefit)
- digital signal corruption
Getting the Signal Out – Buffer Amplifiers

- Initial signals in arrays consist of anywhere between a few and a few thousand electrons.
  - Small capacitances turn these charges into “macroscopic” but delicate voltages.
- Any subsequent component which sucks up charge through significant capacitance or leakage current will obliterate the signal.
  - MOSFET transistors provide an ideal solution
    - an \textit{insulated} “gate” controls current flowing in a conducting channel.
    - as such, a MOSFET is a true “transconductance” device – one which transforms voltage into current without drawing current from the source.

![Diagram of MOSFET](http://info.tuwien.ac.at/theochem/si-srtio3_interface/si-srtio3.html)
Transistors in General

- Bipolar junction transistors (BJTs) consist of a pair of back to back diodes.
  - The “base” (usually the location of the input signal) is reverse biased relative to the “collector” and forward biased relative to the “emitter”
- The flow carriers in the forward bias junction diffuse into the reverse biased junction and substantially modify the current through the device.
- BJTs can be viewed as providing current gain.
  $$I_{CE} = h_{fe} I_B$$
  - since the base-emitter junction is a forward biased diode, there is always an 0.6V drop across this junction as long as the transistor is in the operating regime.
Workhorse BJT Circuits

- Read Horowitz and Hill Chapter's 2 and 3 (for the fundamentals)
  - BJTs are not strictly run in full current-gain mode (left example) – particularly because the gain factor $h_{FE}$ is not well controlled and can vary by a factor of two or more between transistors.
  - Instead, negative feedback (provided by resistors) produce more stable and desirable properties (center and right)

Figure 2.3. Transistor switch example.  Figure 2.6. Emitter follower.  Programmable current source
Using Matched Transistors to Stabilize Circuit Behavior

- Nearly identical transistor pairs are available in a common package.
  - Not only are the transistor properties uniform, their temperature is always identical.
  - The intrinsic properties of one transistor can regulate the other.

Figure 2.45
Horowitz and Hill  The Art of Electronics

Figure 3.15
A Matched Transistor Voltage Follower – A Nearly Ideal Buffer

- The “bottom” transistor is a current source which produces a current characteristic of \( V_{gs} = 0 \)

- The “top” transistor (which is identical to the “bottom”) must adjust to the identical condition, which means relaying the gate voltage to its source terminal.

  - In essence the current source actively behaves like a huge resistor, which leads to ideal follower behavior.

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![Characteristics curves for a typical N-channel JFET.](http://www.st-andrews.ac.uk/~jcgl/Scots_Guide/info/comp/active/jfet/jfetchar/jfetchar.htm)

![Figure 3.28](http://www.st-andrews.ac.uk/~jcgl/Scots_Guide/info/comp/active/jfet/jfetchar/jfetchar.htm)

![Figure 3.29](http://www.st-andrews.ac.uk/~jcgl/Scots_Guide/info/comp/active/jfet/jfetchar/jfetchar.htm)
Data Collection – Analog to Digital Conversion

- Detectors convert photon flux into measurable voltages.

- A graduate student and a voltmeter do not, however make for an efficient system – although it sufficed for many decades (e.g. the TMSS data was collected via strip chart recorder).

- Digital-to-analog converters linearly transform binary numbers to a proportional voltage.

- They can then be used, in turn, to compare with incoming signals.

![Figure 9.46. R-2R ladder. The Art of Electronics (Horowitz and Hill)](image-url)
Analog-to-Digital Conversion

- Since ADC's provide a connection between the analog and digital world they can be used to convert analog signals into digital data.

- Simply ask, what digital input to an ADC will produce an analog voltage which matches the voltage of interest.
ADC data is useless unless it can be read into computer memory.

More circuitry is required to interface the ADC output to the computer bus.

In reality, the gory detail is hidden from the experimenter through software/hardware interfaces ranging from primitive (assembly language) to sophisticated (Labview) – both have their advantages.

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**Figure 10.1. Block diagram of a computer.**
The Art of Electronics (Horowitz and Hill)
ADC data is useless unless it can be read into computer memory.

More circuitry is required to interface the ADC output to the computer bus.

In reality, the gory detail is hidden from the experimenter through software/hardware interfaces ranging from primitive (assembly language) to sophisticated (Labview) – both have their advantages.

Figure 10.9. I/O READ cycle.

Figure 10.10. Parallel input port.
Computer Bus Interface

- ADC data is useless unless it can be read into computer memory.
- More circuitry is required to interface the ADC output to the computer bus.
- In reality, the gory detail is hidden from the experimenter through software/hardware interfaces ranging from primitive (assembly language) to sophisticated (Labview) – both have their advantages.

![Computer Bus Interface Diagram](image)

Figure 10.11. Keyboard interface with status bit.