Opto electronics

= light sources & light detectors

textbook section 9.10

Applications of opto-electronics

indicators

- LED shows ON/OFF or ok/NOT-ok on front panel of your instrument

↑ oral story: paddle wheel switch → LED indicate water flow & interlock status in high-power scientific instrument like a laser

displays

- digital display, like calculator
- in lab you use 7-segment LED display

isolation

electrically isolate two circuits by sending signal optically

why:
- safety

  reactor room
  ↕ optical cable
  control room

- separate power supplies

show viewgraphs:
- pulser circuit for electron beam
- data sheet page for optoisolator

fiber-optic transmission

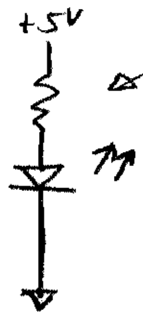
transmitter
↓ fiber
receiver

why:
- avoid noise pickup
  oral story: thesis project
- long-distance data transmission

Opto electronic devices

- semiconductors (typically GaAs & similar, not Si)
    - Laser diode
    - LED
    - photodiode
    - phototransistor
    - CCD or CMOS imaging
- vacuum
    - PMT (photo multiplier tube)

LEDs



← current-limiting resistor typ. 270Ω

← colors IR, red, yellow, green, blue, white

(blue, white) ← newer technology

packages

- for front panel, use a "bezel" to mount in hole
- arrays of LEDs for bargraph indicator

__limiting resistor:__ determines current consumption

$$I = \frac{V}{R}$$

$$= \frac{5V}{270\Omega}$$

$$= 19\ mA$$

↑ a lot, especially if you use lots of LEDs

__speed__ you measured rise time > 30 nsec in Lab 6

Laser diode

looks similar to LED, but:

- more monochromatic
- switches ON/OFF much faster (n sec)

just provide a power supply

Photo transistor

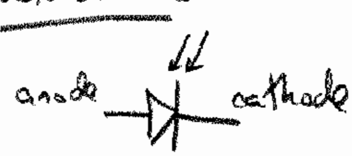
like an npn transistor, except:

- transparent case
- light hits base - collector junction, & photons generate electron current at base
- more light ⇒ more base current

speed:

you measure rise time ~ 4 μsec in Lab 6

Photo diode



photon excites electron in pn junction, then electron flows to cathode

so light ⇒ current

compare:

	phototransistor	photodiode
different	has current gain	no current gain
	slower (~μs) response time	faster (~nsec)

minimum detectable light level is about the same

photodiode use:

- zero bias ⇒ photovoltaic mode
  used for solar cells

- reverse bias ⇒ photoconductive mode
  provides fast rise time for detecting signals

- avalanche
  big reverse bias
  ⇒ electrons multiplied by "avalanche breakdown"
  ⇒ [illegible]

detector terminology:

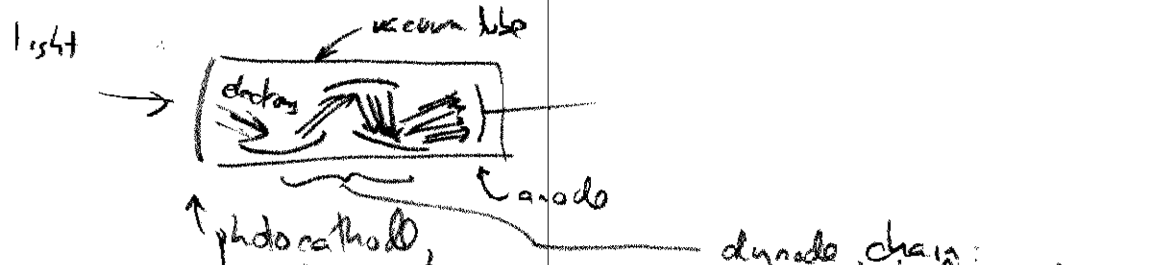
"responsivity" = ratio of $\frac{\text{generated photocurrent}}{\text{incident light power}}$

"quantum efficiency" = ratio $\frac{\text{number of photogenerated electrons}}{\text{number of incident photons}}$

↑ dimensionless quantity, typically ~ 10%

PMT photomultiplier tube

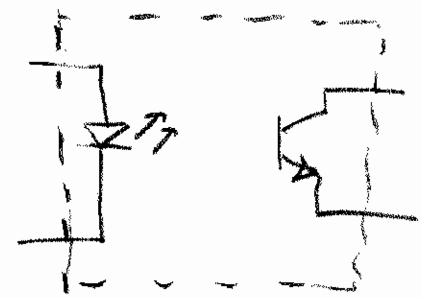
- a competitor to avalanche photo diode
- fast (~ 1 sec)
- efficient
- requires HV supply (like avalanche photodiode)
- applications:
  - particle physics scintillation detector
  - spectroscopy labs



Opto isolators

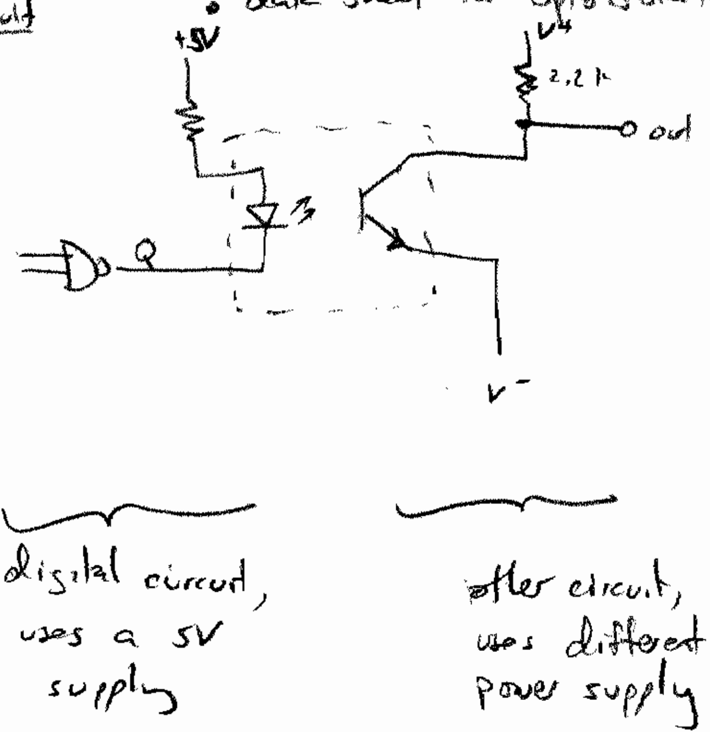
package w/ LED & phototransistor
in same package

ex 4N35



show viewgraphs:
- pulser circuit for e-beam
- data sheet for optoisolator

example circuit



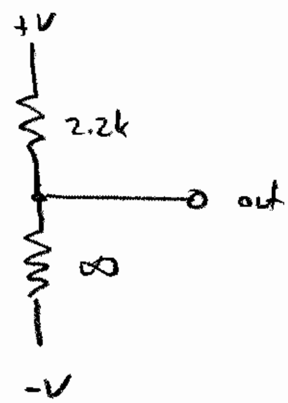
in this example:

- when Q is HI

  LED is OFF

  → no base current on transistor

  right half of
  circuit looks like:



  so output voltage is +V

- when Q is LO

  LED is ON

  → lots of base current in transistor

  → transistor conducts

  right half of circuit looks like

so output
voltage is ≈ -V →