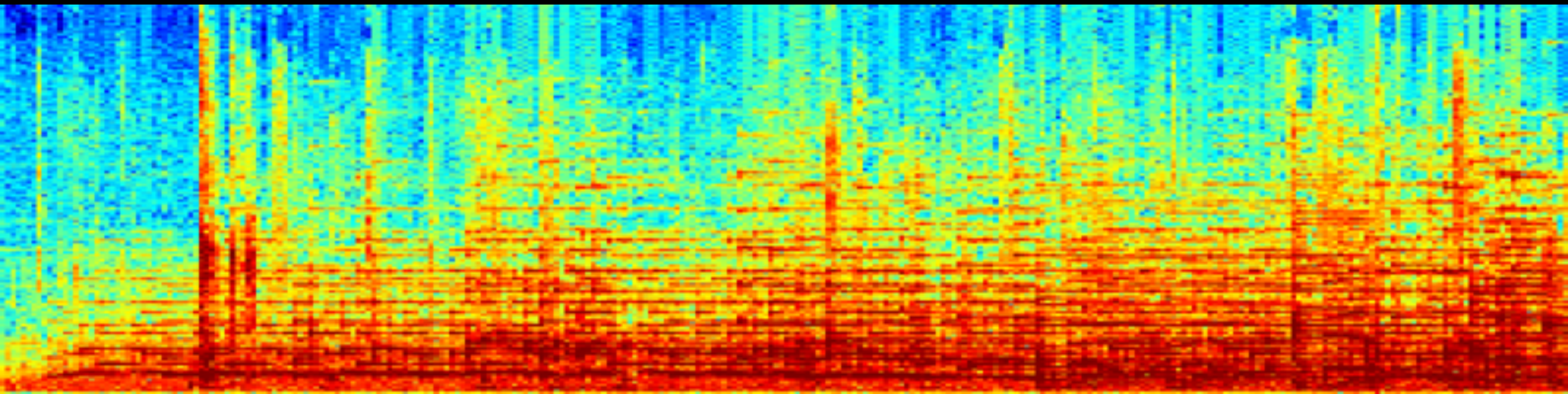
Measurement Systems with Electrical Signals
Wheeler & Ganji Chapter 3



BK Precision 1666 DC power supply

- Rated to 40 V, 5 A
- What load resistance drops 40 V with a 5-A current?

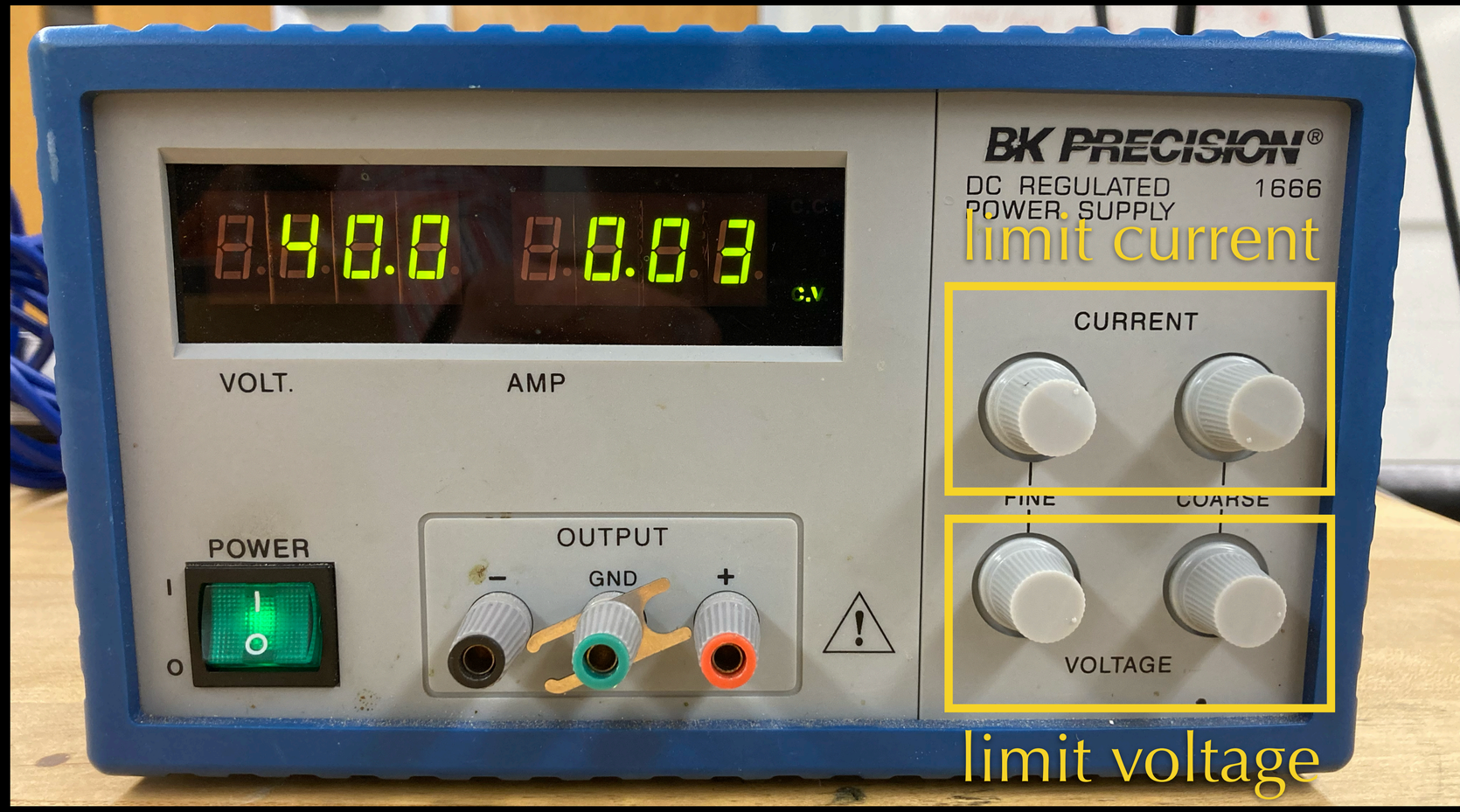
$$R = V/I = 8\ \Omega$$

- How much current can this power supply drive through a 20 Ω load?

$$I = (40\ \text{V})/(20\ \Omega) = 2\ \text{A}$$

voltage limited

- How much voltage can this supply drop across a 4 Ω load?



$$V = (5\ \text{A})(4\ \Omega) = 20\ V$$

current limited

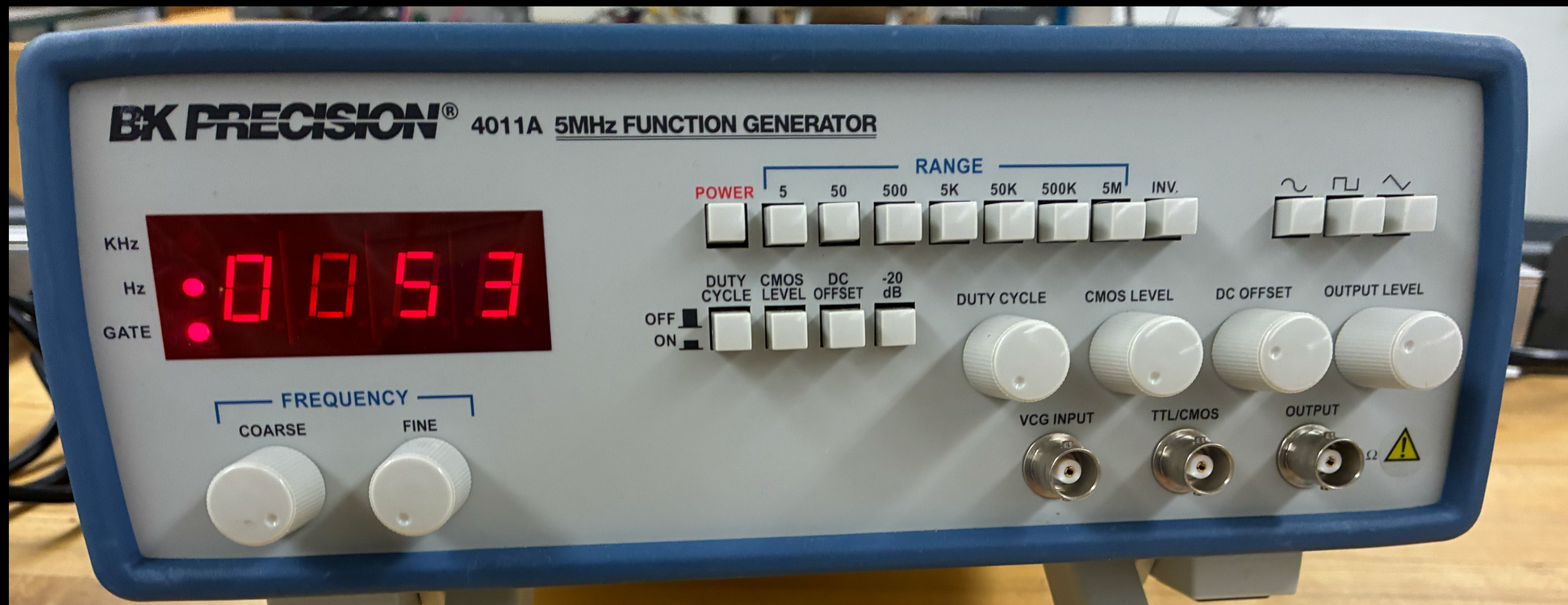
BK Precision 4011A function generator

- Produces periodic voltages: sinusoid, square, or triangle
- Adjustable amplitude (“output level”), frequency, and DC offset

amplitude frequency DC offset

$$V_o = A \sin(2\pi f t) + B$$

output voltage time



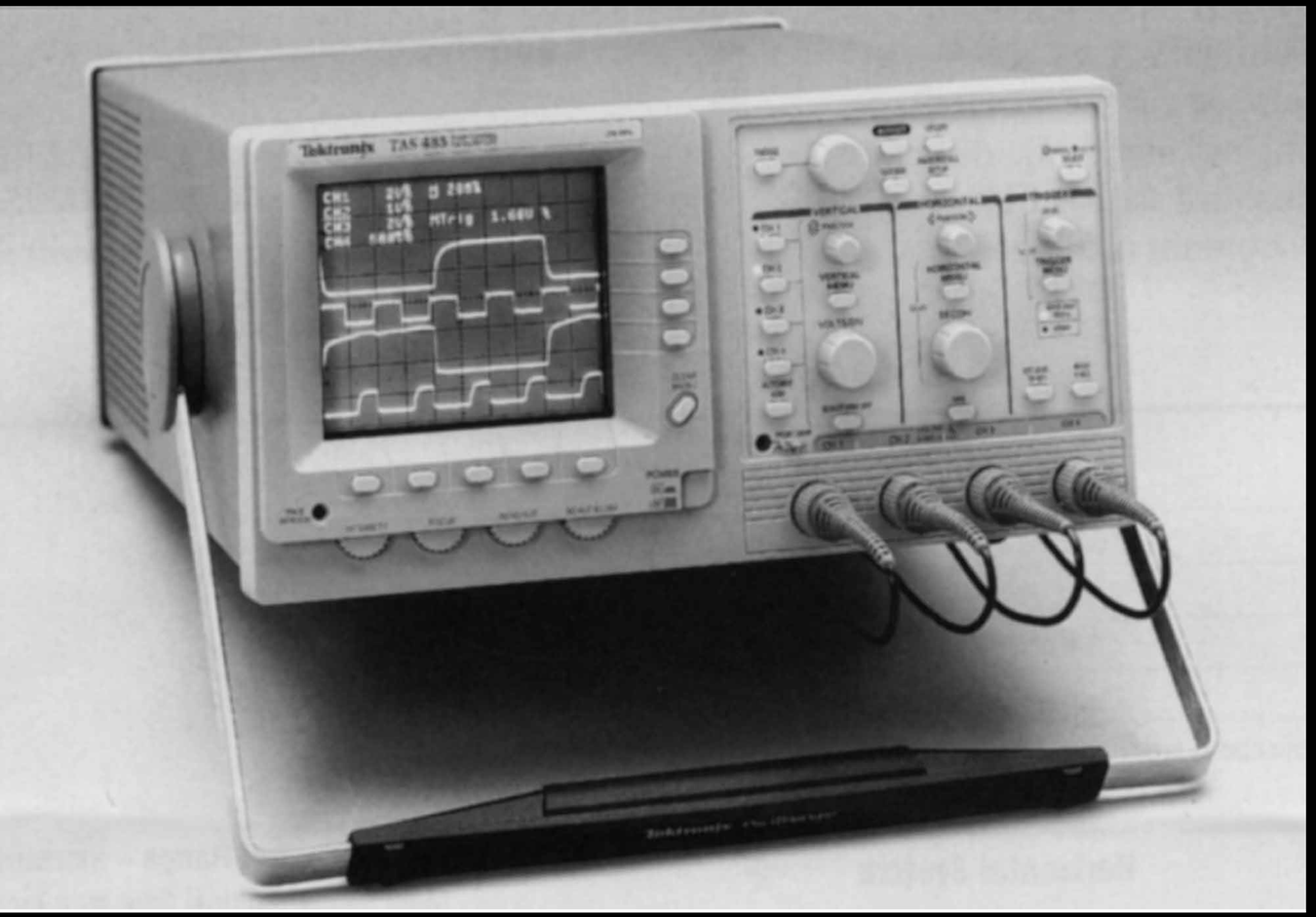
transducer (n): a device that converts a physical parameter (e.g., temperature, pressure, force, volume) into an electrical signal or vice versa

Digital multimeter



- High input impedance for voltage measurements
- Low input impedance for current measurements
- DC or AC
- Can measure resistance
- Some can measure capacitance, read thermocouples, …
- Accuracy <1% of reading
- Measure voltage by applying it *across* meter terminals
- Measure current by driving it *through* meter
- Not working? Check leads, battery, and fuse!

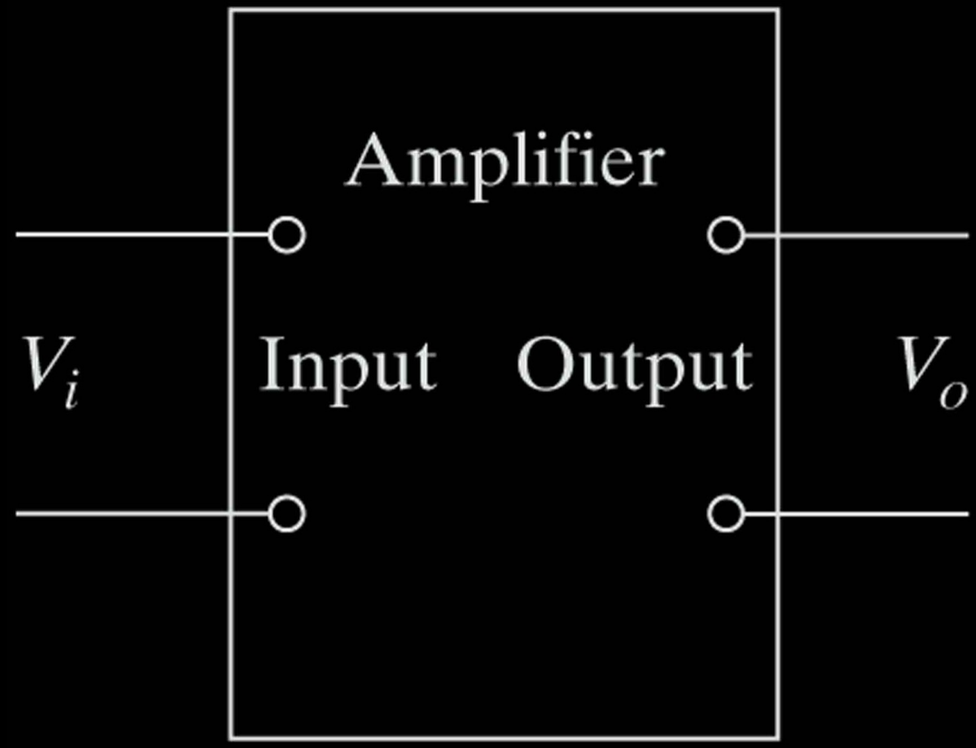
Oscilloscope



- For measuring time-varying voltages, typically periodic
- High input impedance
- Accuracy <1% of reading
- Multiple channels
- Up to 100 MHz
- Usually USB output
- Unexpected signal amplitude? Check probe gain

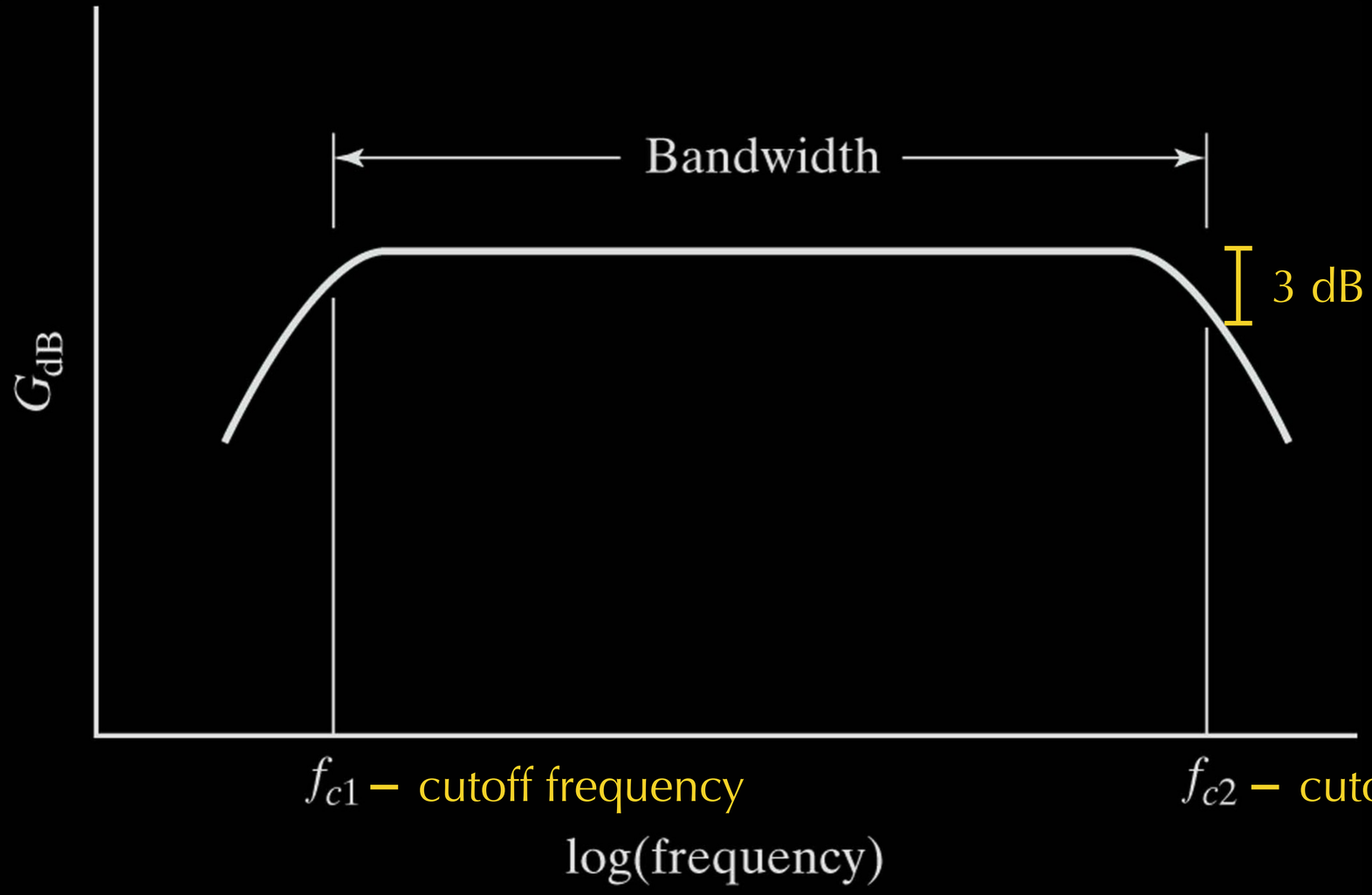
Amplifiers

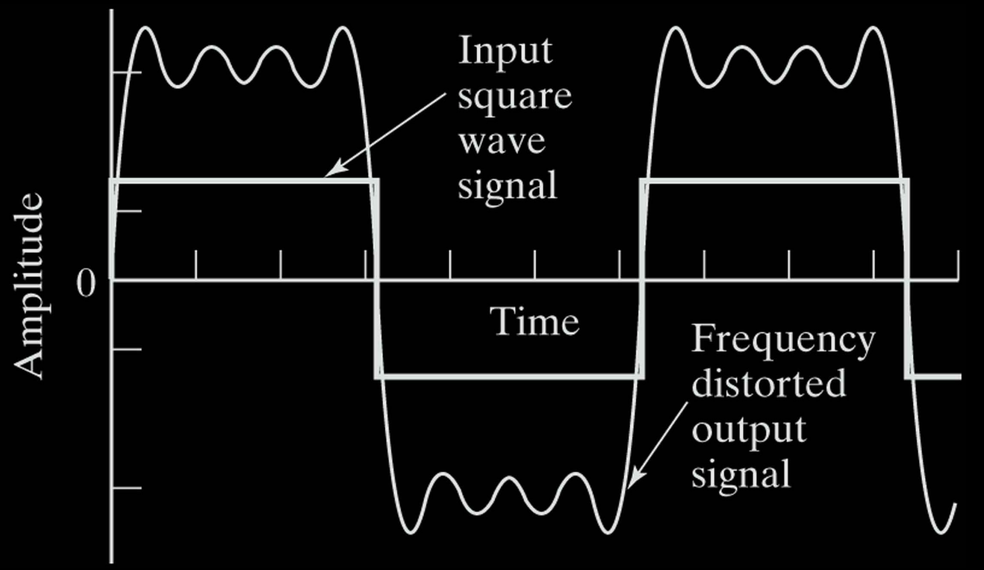
- **amplifier** (n): an electronic device for increasing the amplitude of electrical signals
- Most voltmeters are best with signals on the order of volts (not, e.g., mV or μV)
- Key parameter: gain $G = \frac{V_o}{V_i}$ — V_o – output voltage; V_i – input voltage
- $G < 0$ "inverting"; $G > 0$ "non-inverting"
- Often expressed in decibels: $G_{\text{dB}} = 20 \log_{10} G$
  - If $G = 10$, what's G_{dB}? 20 dB
  - If $G = 100$, what's G_{dB}? 40 dB
  - If $G = 1000$, what's G_{dB}? 60 dB
  - If $G = 0.1$, what's G_{dB}? -20 dB



Amplifier bandwidth

- Gain is nearly constant over some range of frequencies — but not at all frequencies.



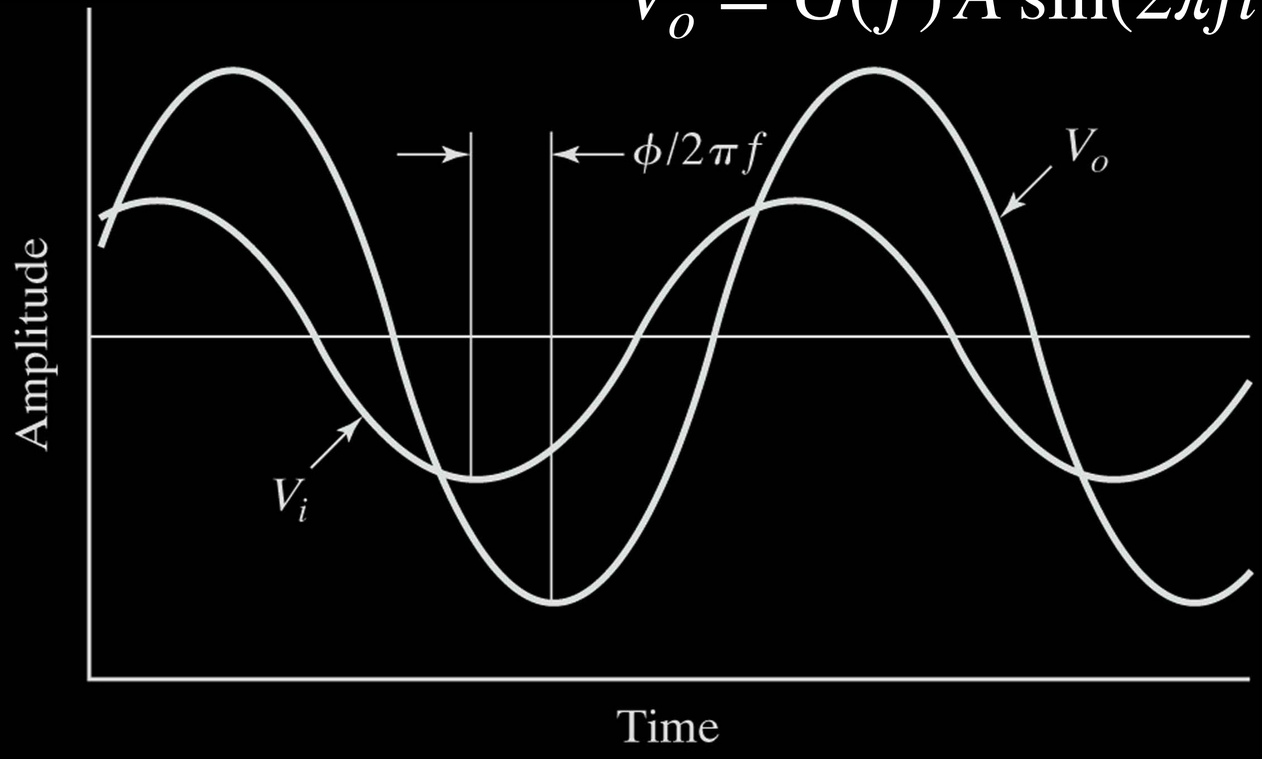


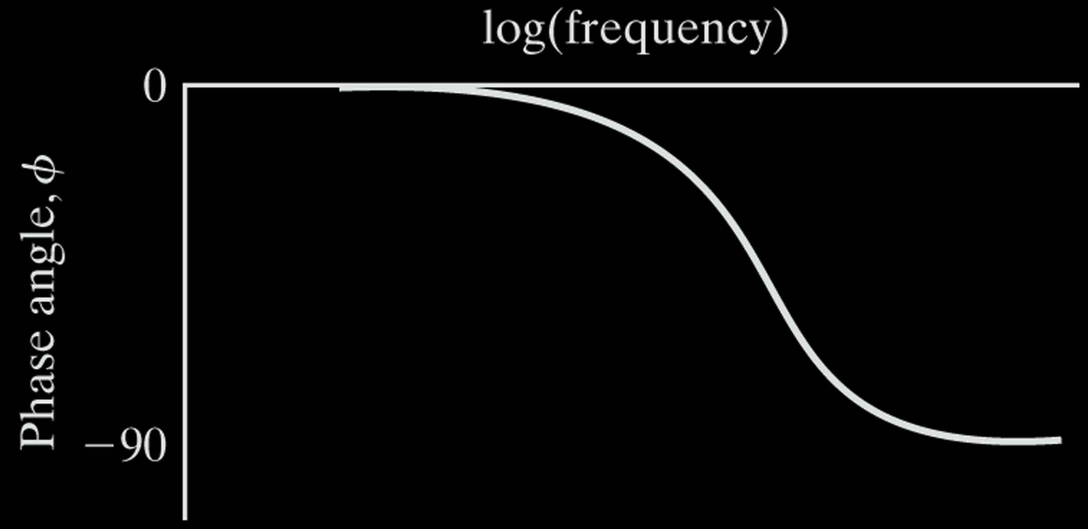
Amplifier phase distortion

- An amplifier alters a signal's phase in a way that varies with frequency.
- Unless $\phi(f) \propto f$, the shape of the waveform is distorted by the amplifier.

frequency phase shift

$$V_o = G(f)\,A \sin(2\pi f t - \phi(f))$$





$$V_i = A \sin 2\pi f t$$

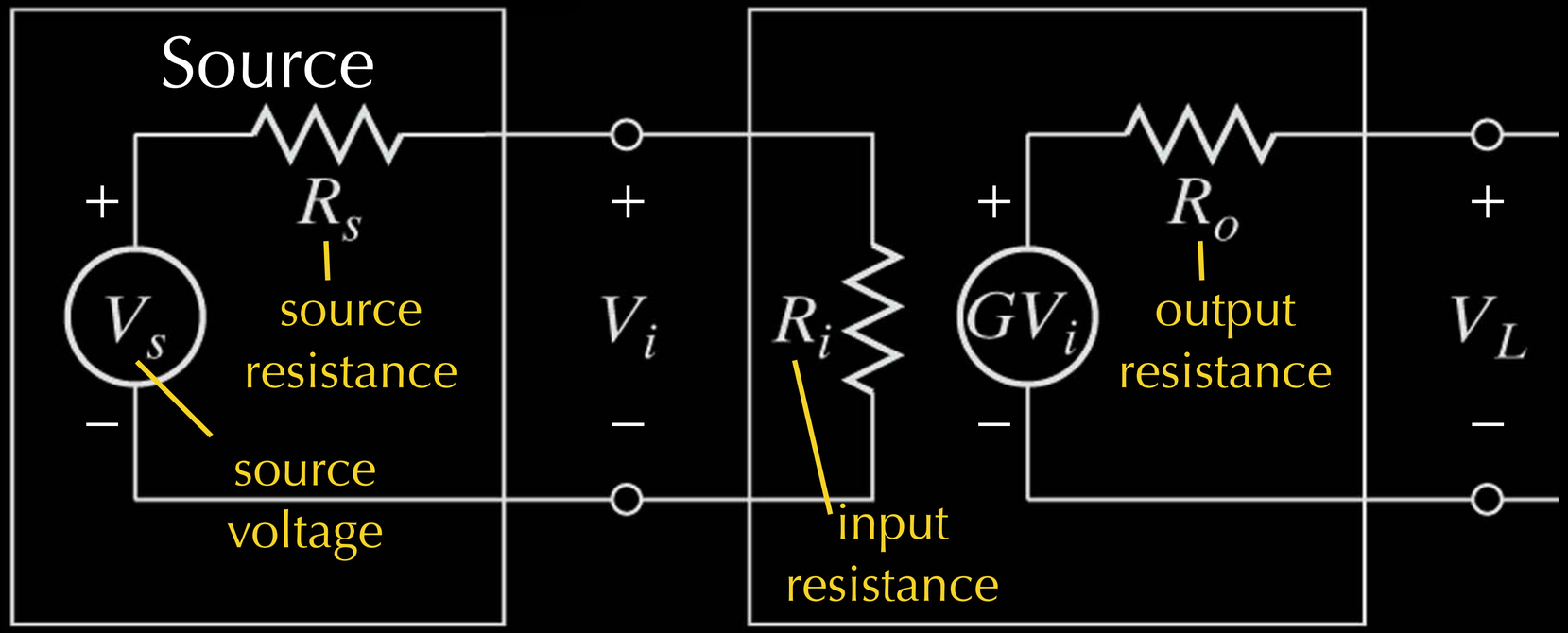
Amplifier loading errors

- Input pins and output pins connect internally with finite resistance.
- Sources have resistance, too. Open-circuit voltage? V_s
- With source connected, V_i?

$$V_i = \frac{R_i}{R_s + R_i} V_s < V_s$$

- How to make $V_i \approx V_s$?

$R_i \gg R_s$ – large input resistance

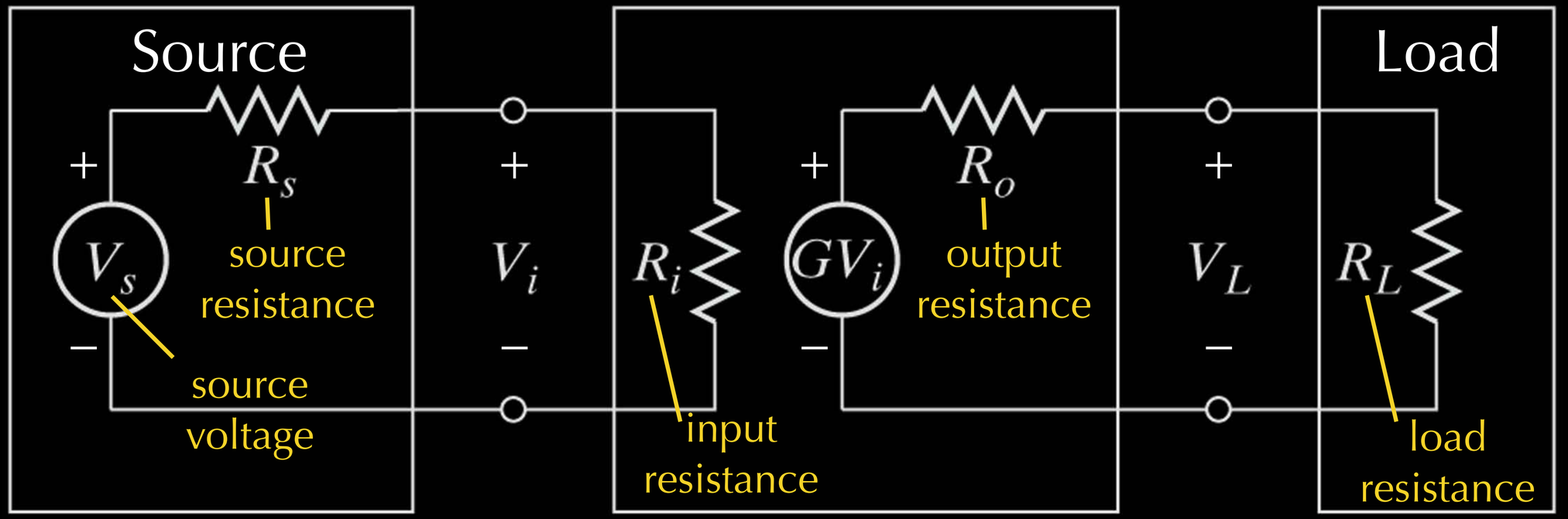


Amplifier loading errors

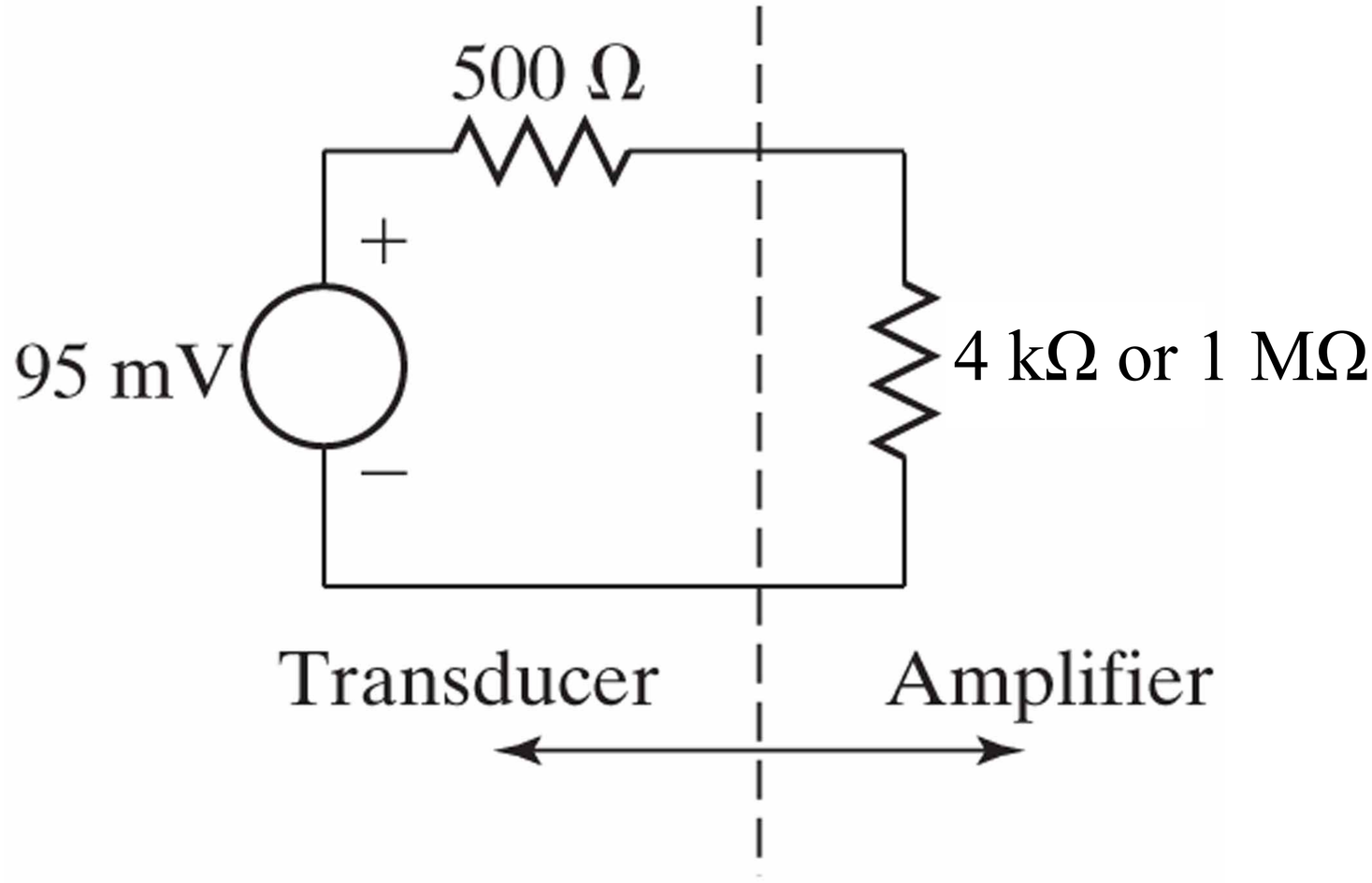
- Loads have resistance, too. V_L, when load is connected to amplifier?

$$V_L = \frac{R_L}{R_o + R_L} G V_i < G V_i$$

- How to make $V_L \approx G V_i$? $R_o \ll R_L$ – small output resistance

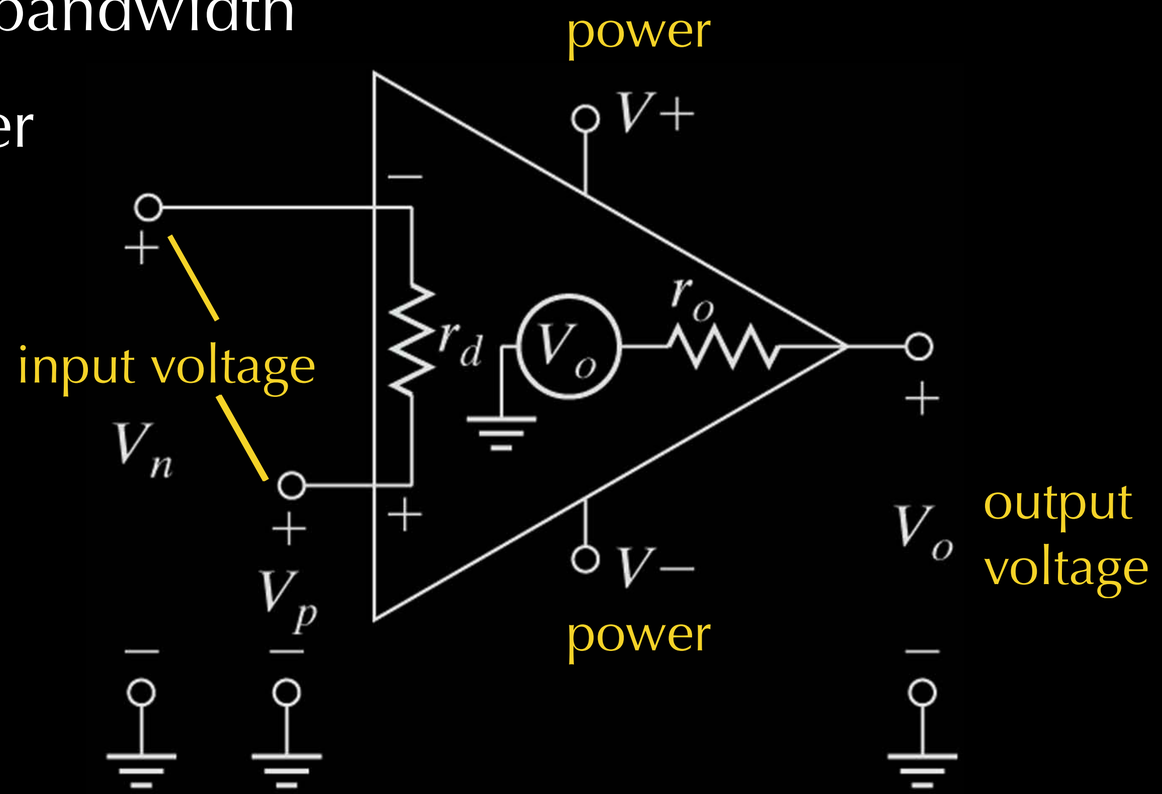


Ex. 3.1: A force-measuring transducer has an open-circuit output voltage of 95 mV and an output impedance of 500 Ω. To amplify the signal voltage, it is connected to an amplifier with a gain of 10. Estimate the input loading error if the amplifier has an input impedance of (a) 4 kΩ, or (b) 1 MΩ.



Operational amplifiers

- An operational amplifier (“op-amp”) is an electronic component useful for making amplifier circuits.
- Common model: μA741C (many manufacturers). Will use in the lab.
- Op-amps have large input resistance (2 MΩ for μA741C), small output resistance (75 Ω), big gain (200,000 ↔ 106 dB), big bandwidth
- Don’t want gain 200,000! Gain of amplifier circuit is set by other components.



UA741CP



Images are for reference only
See Product Specifications

Share

Mouser #:	595-UA741CP
Mfr. #:	UA741CP
Mfr.:	Texas Instruments
Customer #:	Customer #
Description:	Operational Amplifiers - Op Amps GP Op Amp
Datasheet:	UA741CP Datasheet
ECAD Model:	PCB Symbol, Footprint & 3D Model

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Differential amplifier circuit

- Output depends on the *difference* between input pin voltages.
- $V_o = \frac{R_2}{R_1}(V_2 - V_1)$
- Good for instruments because isolated from (possibly noisy) ground connection.
- Q: What's the gain? R_2/R_1
- Other amplifier types: inverting, non-inverting, …
- Gain is always set by resistor values (e.g. R_1, R_2, …)

