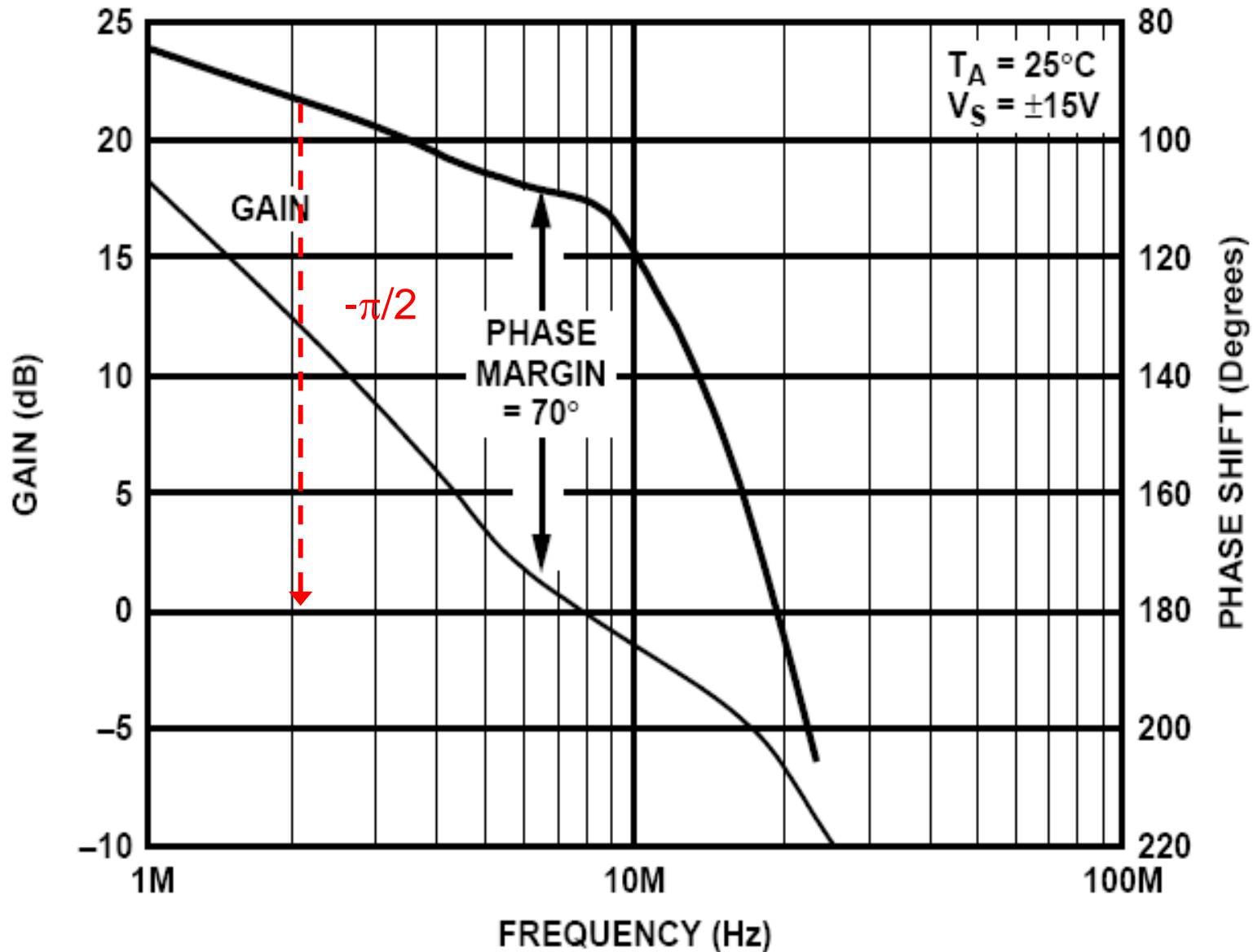


# Op-amp Buffet

## ***MENU:***

- Op-amps and complex impedances.
  - **Integrators** and active low-pass filters.
  - **Differentiators** and active high-pass filters.
  
- Op-amps and **power amplifiers**.
  - Op-amps with transistor outputs.
  
- Op-amp **constant current sources**.
  
- Op-amps and **photodiodes**.

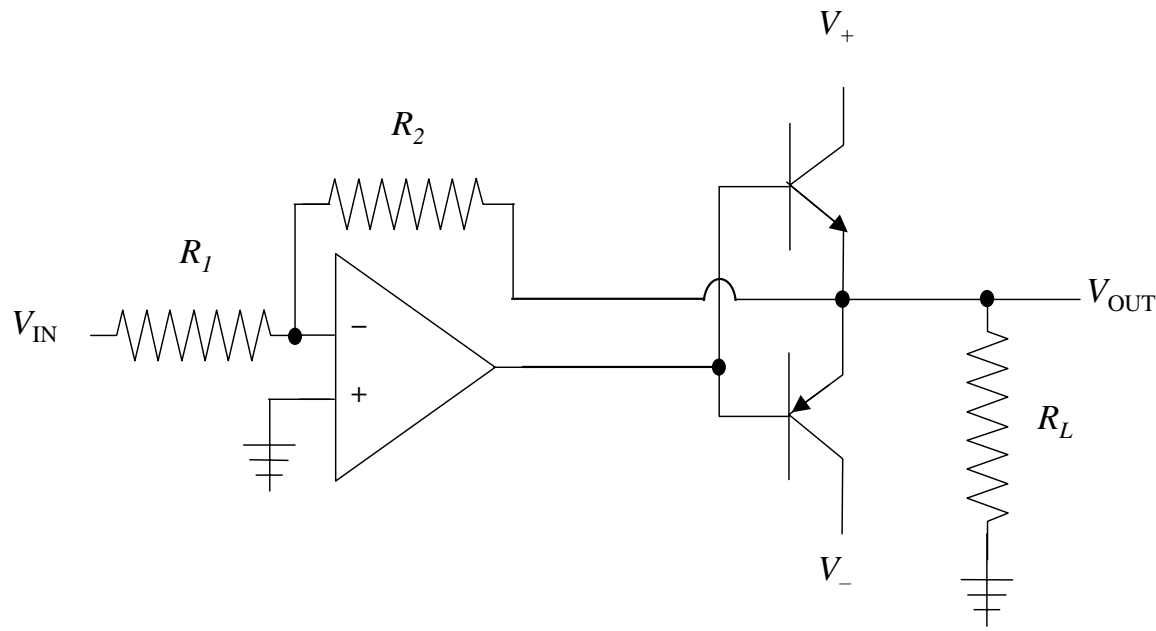
# Watch out for positive feedback !!!



# When would you use an op-amp integrator or differentiator?

- **Do not use an op-amp for a high-pass or low-pass filter.**
  - R and C components work up to very high frequencies, but op-amps have limited bandwidth.
  - **exception:** RC op-amp circuits can imitate the impedance of a perfect inductor → make ideal “RLC” circuits.
- RC op-amp circuits are good if you need a true differentiator or integrator, or very high fidelity performance.
  - more on this next week.
  - A true integrator can measure charge (particle physics).
- Integrators and differentiators were the basis of analog computers (outdated).

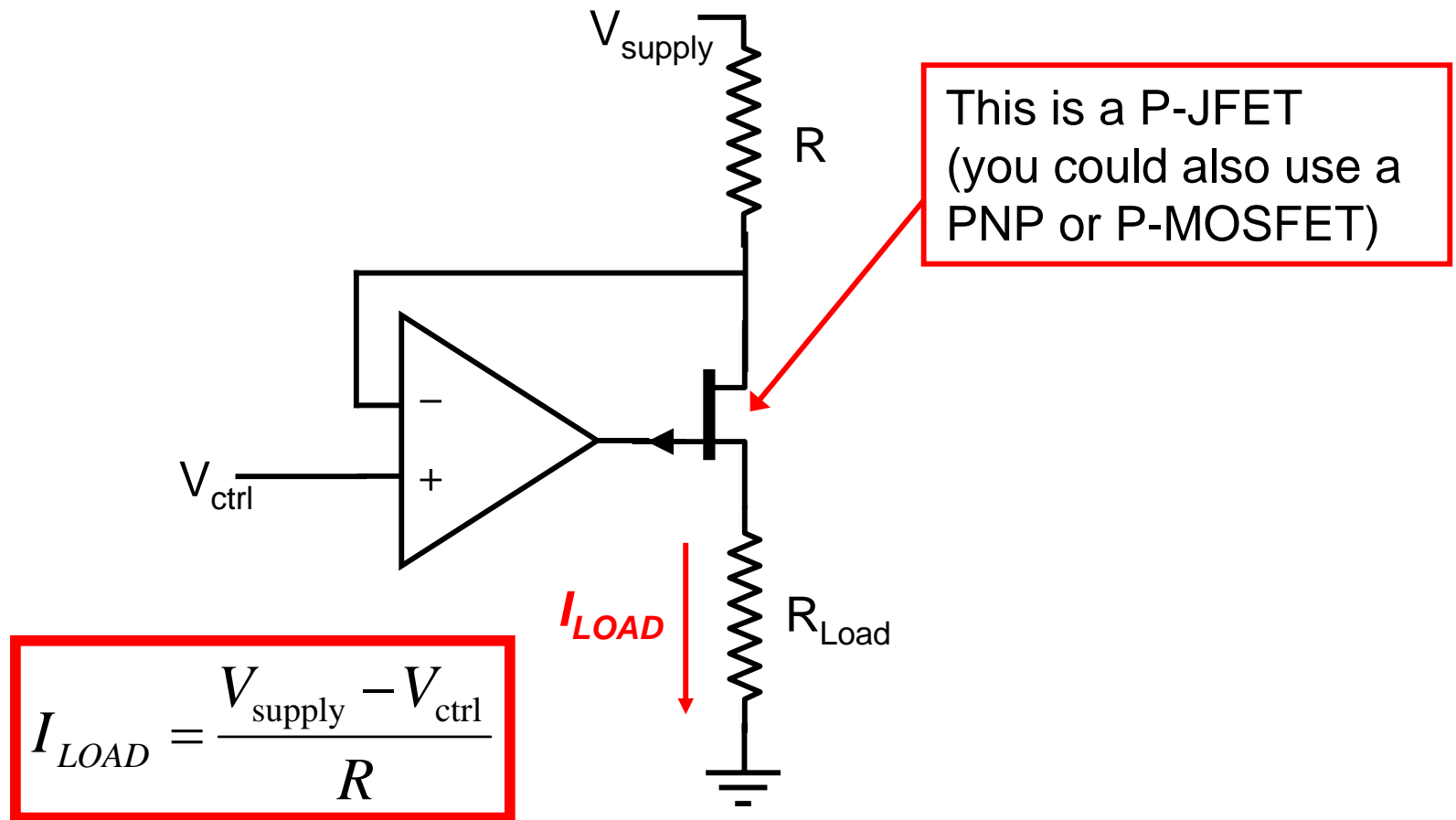
# Op-amps for power amplifiers



Inverting amplifier with a push-pull buffer  
inside the feedback loop.

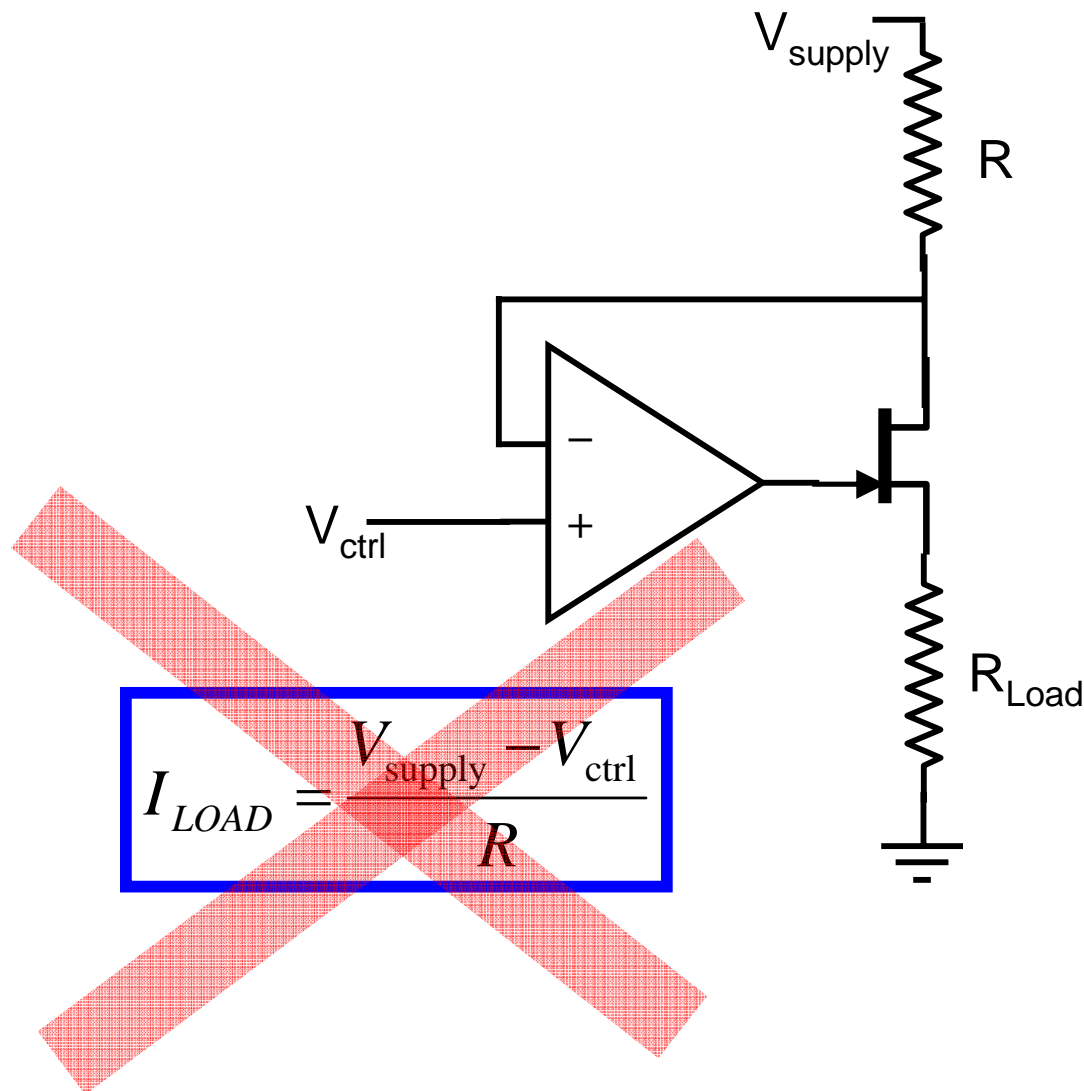
If the signal is not too fast (i.e. slower than the slew rate  $\sim 1 \text{ V}/\mu\text{s}$ ), then the feedback of the op-amp will significantly suppress cross-over distortion (which is due to the 0.6 V diode drop of the base-emitter path).

# Constant Current Source with Grounded Load

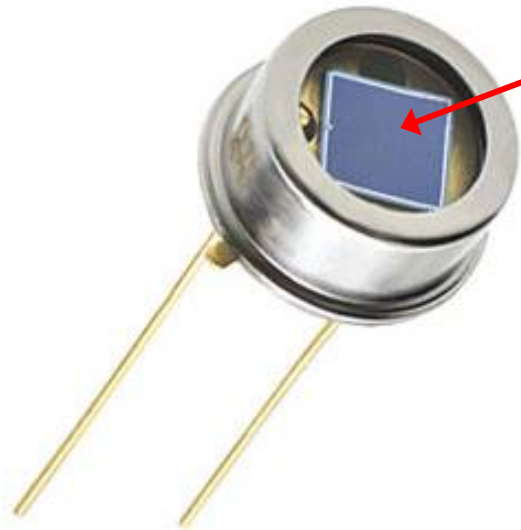


# Bonus Question:

## Why doesn't this circuit work? (as a constant current source)

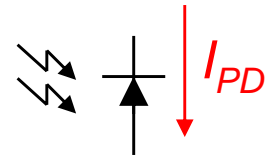


# Photodiodes and Op-amps



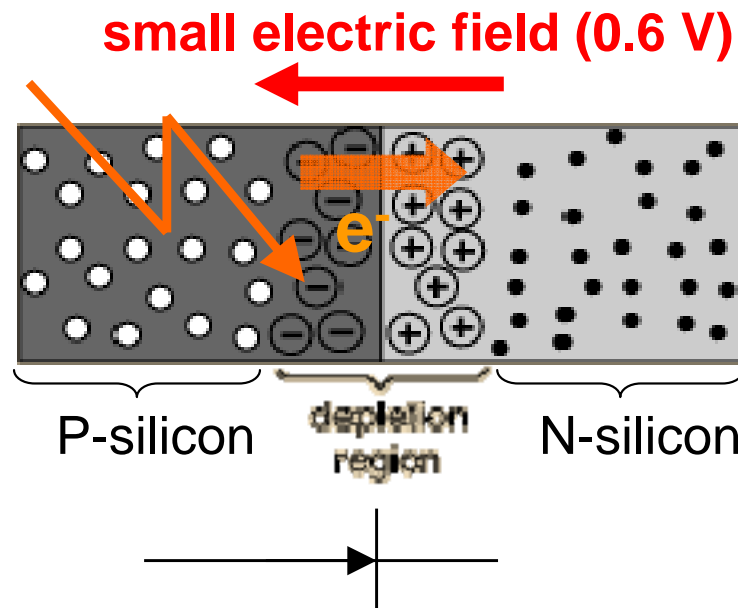
Light sensitive area

- Each incident photon will produce about 0.5-0.9 photo-electrons.
- The photo-current goes in the “wrong” direction.



FDS100 photodiode

[Image from [www.thorlabs.com](http://www.thorlabs.com)]

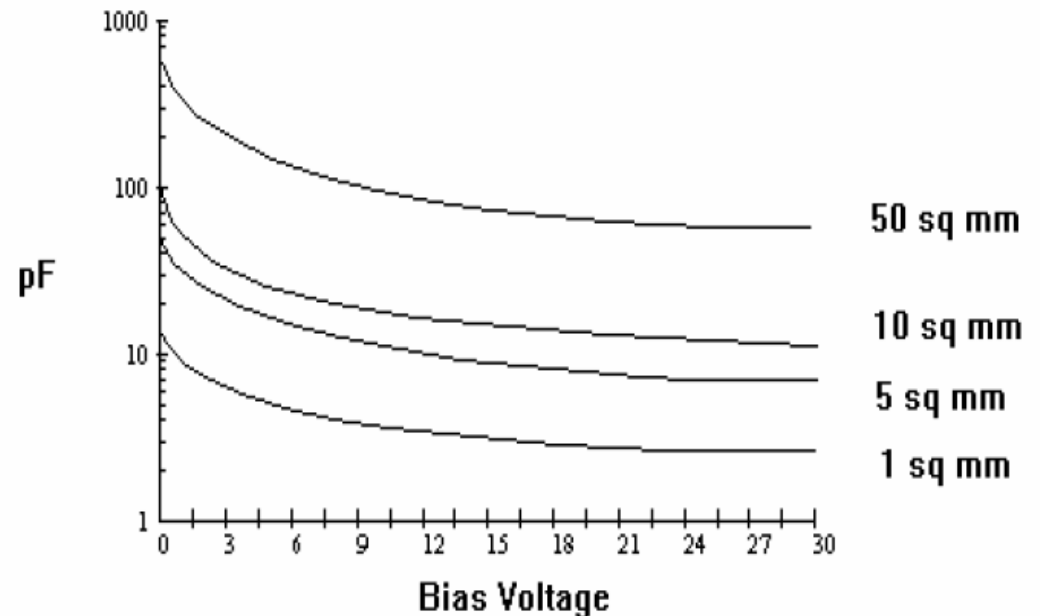


- electron
- hole
- ⊖ negative ion from filled hole
- ⊕ positive ion from removed electron

# Reverse-biasing Photodiodes

## Why use reverse-biasing?

- It reduces the PN junction **capacitance**.  
→ **Faster time response**.
- It improves the **linearity** of the photo-current (i.e. photo-electrons per photon) at higher illumination.



[figure from [www.centrovision.com](http://www.centrovision.com)]