ECE 145C / 218C, notes set xx: Automatic Gain Control (very quick summary)

Mark Rodwell
Doluca Family chair
University of California, Santa Barbara

rodwell@ece.ucsb.edu

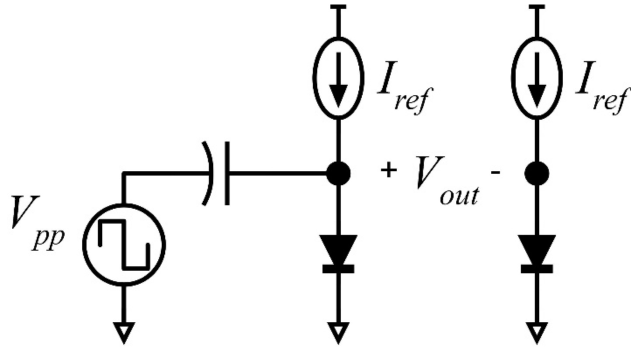
Power detectors & peak detectors

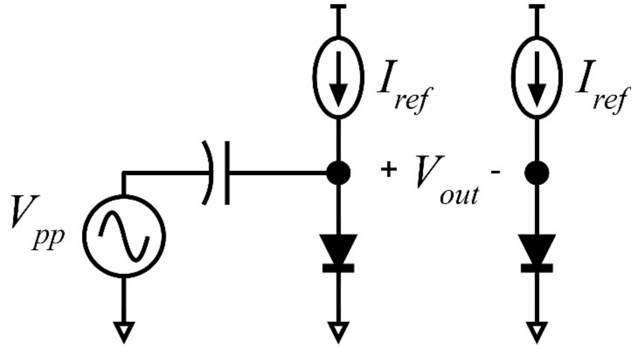
Square-wave drive (easy analysis)

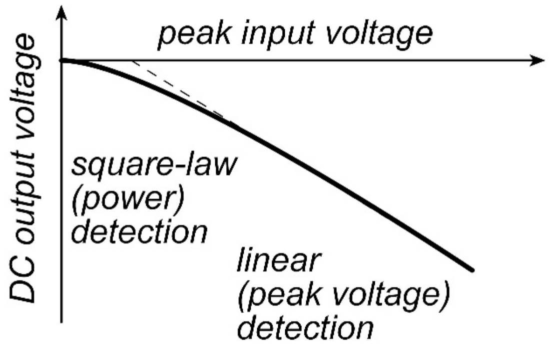
$$\exp\left(\frac{V_{out}}{nkT/q}\right)=\left(\exp\left(\frac{V_{pp}}{2nkT/q}\right)+\exp\left(\frac{-V_{pp}}{2nkT/q}\right)\right)^{-1}$$

$$V_{out}\approx\begin{cases}-\left(\frac{V_{pp}}{2}-\frac{nkT}{q}\ln(2)\right)\text{ (peak detection)} & \text{if } V_{pp}>>\frac{nkT}{q}\\ -\frac{V_{pp}^2}{2nkT/q}\text{(power detection)} & \text{if } V_{pp}<<\frac{nkT}{q}\end{cases}$$

This will be derived in lecture





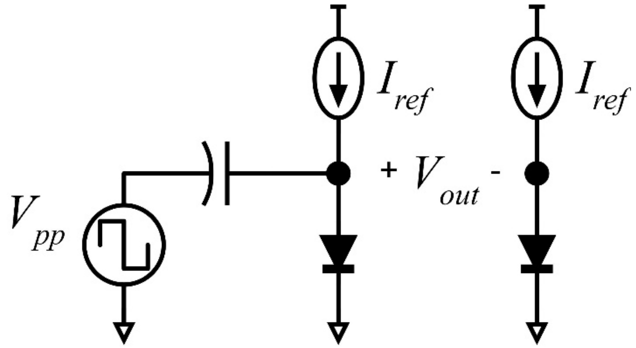


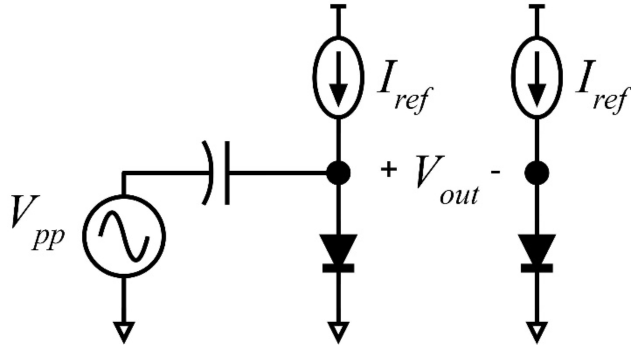
Power detectors & peak detectors

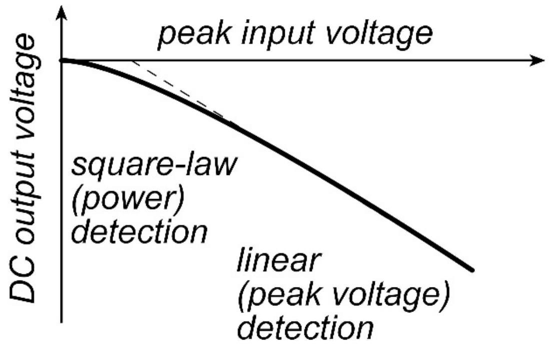
Sinusoidal drive (more difficult analysis)

$$V_{out} \approx -\frac{V_{peak}^2}{4nkT/q} \text{(power detection) if } V_{pp} << \frac{nkT}{q}$$

this will again be derived in lecture







AGC detector, set point, and AGC loop amplifier

$I_{REF1} / I_{REF2} = R_2 / R_1$

So, if $V_{pp} = 0$ V,

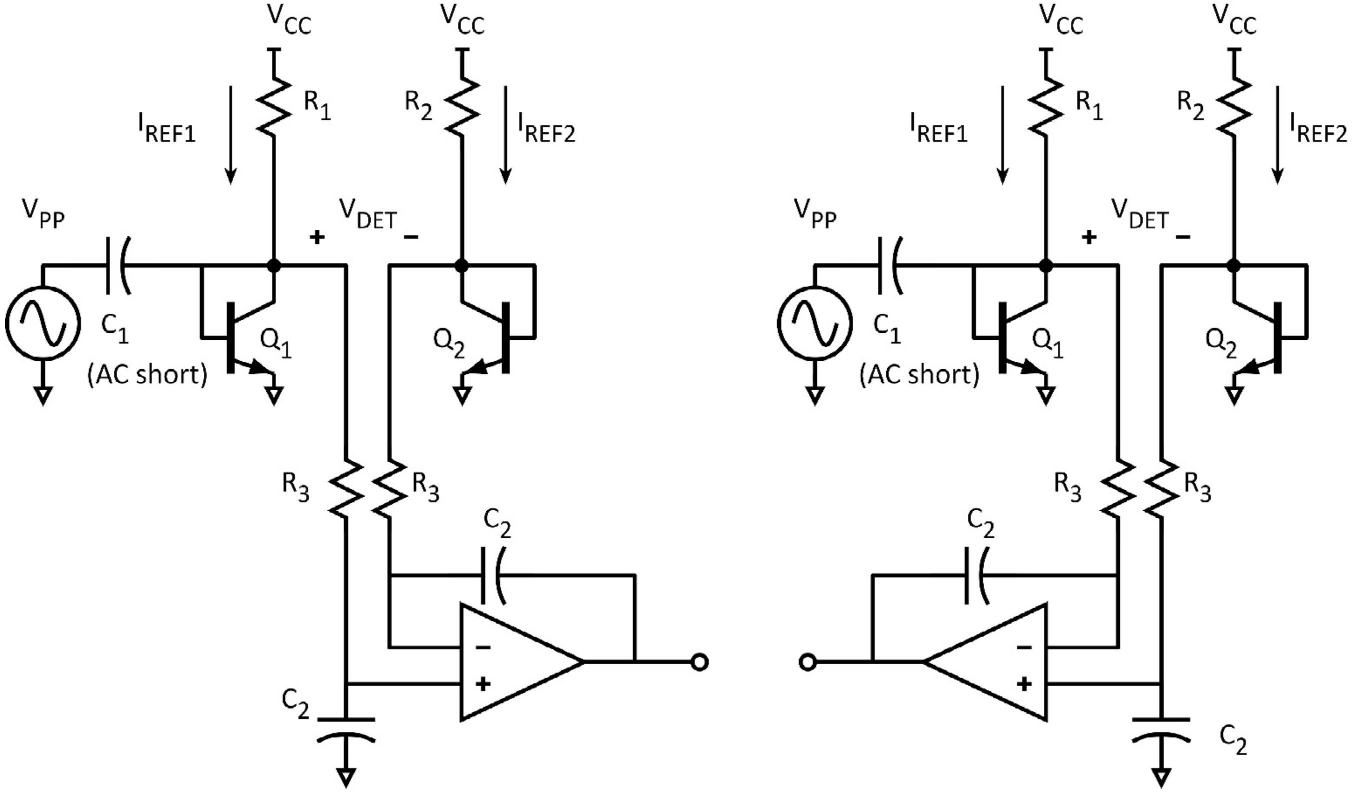
$$V_{DET} = \frac{nkT}{q} \ln\left(R_2 / R_1\right)$$

Given sinusoidal drive with $V_{pp} << nkT / q$

$$V_{DET} \approx \frac{nkT}{q} \ln\left(R_2 / R_1\right) - \frac{V_{peak}^2}{4nkT / q}$$

Loop stabilizes when $V_{DET} = 0$ V, hence

$$V_{peak} = 2\frac{nkT}{q}\sqrt{\ln\left(R_2 / R_1\right)}$$



Need R_1, R_2 , and R_3 all $>> nkT / qI_{REF}$

If needed, exchange the polarity of the connection to V_{DET} to obtain the correct sign of AGC loop gain

AGC detector, set point, and AGC loop amplifier

You can also set up an offset like so...

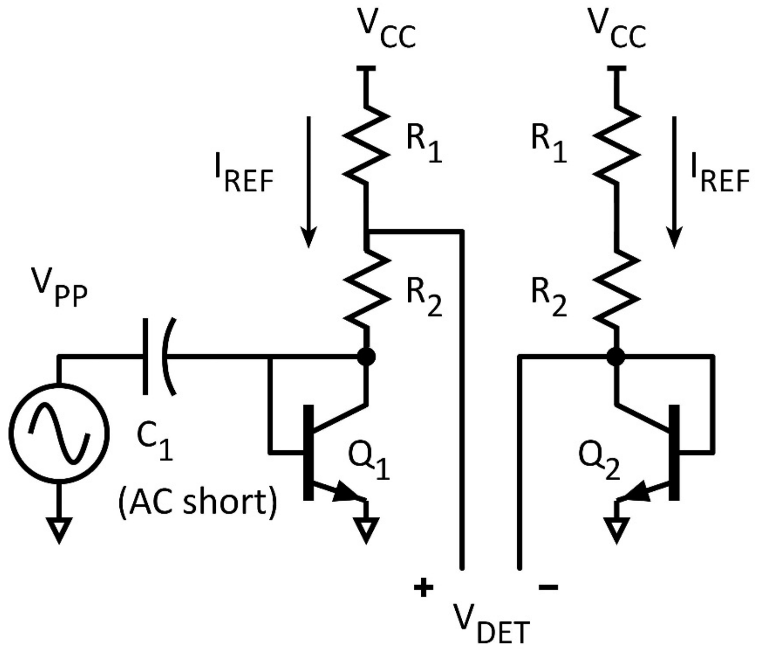
With $V_{pp} = 0$ V,
$V_{DET} = I_{REF} R_2$

Given sinusoidal drive with $V_{pp} << nkT/q$

$$V_{DET} \approx I_{REF} R_2 - \frac{V_{peak}^2}{4nkT/q}$$

Loop stabilizes when $V_{DET} = 0$ V, hence
$V_{peak}^2 = (I_{REF} R_2)(4nkT/q)$

Need R_1, R_2 , and R_3 all $>> nkT/qI_{REF}$
If needed, exchange the polarity of the connection to V_{DET}
to obtain the correct sign of AGC loop gain



Mixer vs. variable-gain amplifier

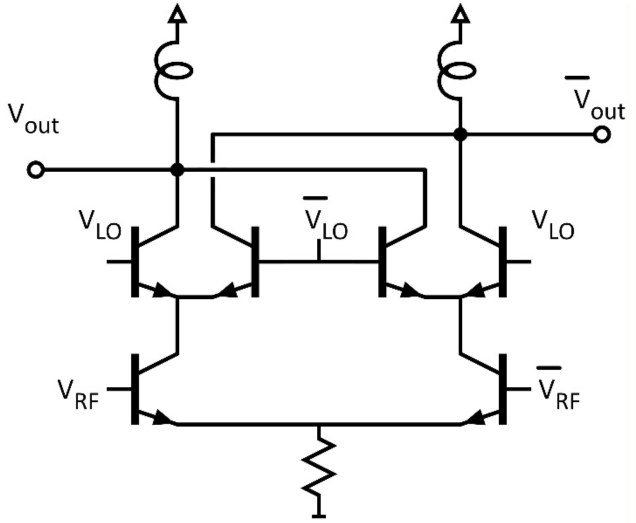
Mixer

$V_{out} = \kappa V_{RF} V_{LO}$ for some constant κ

For large positive V_{LO} : $V_{out} = \kappa V_{RF}$

For large negative V_{LO} : $V_{out} = -\kappa V_{RF}$

AGC loop will not function correctly



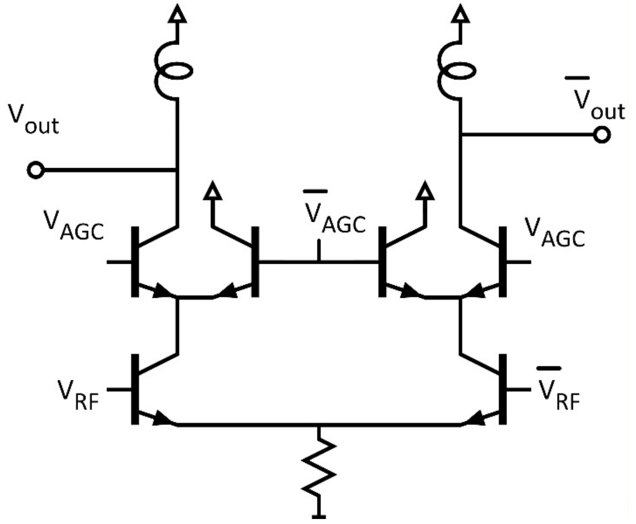
Variable-gain amplifier

$V_{out} = A_v V_{RF}$

For large positive V_{AGC} : A_v is large

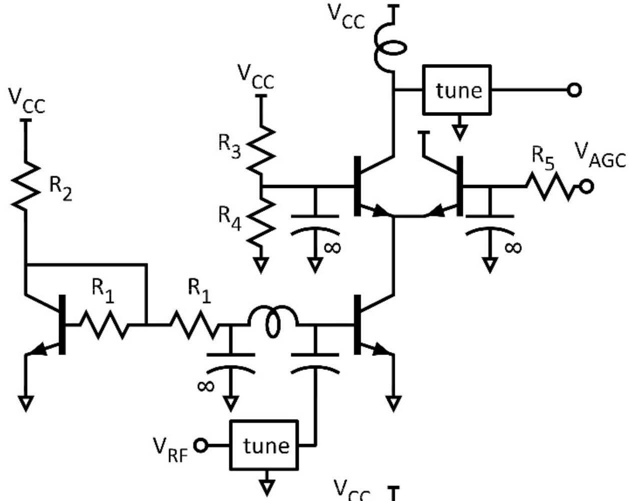
For large negative V_{AGC} : A_V is zero

AGC loop will function correctly

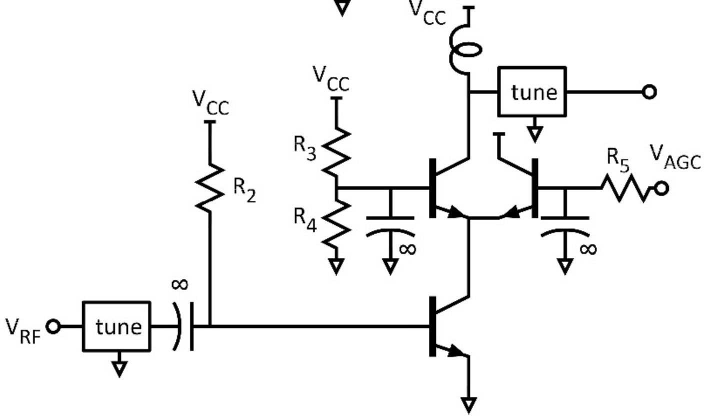


Simpler variable-gain amplifiers

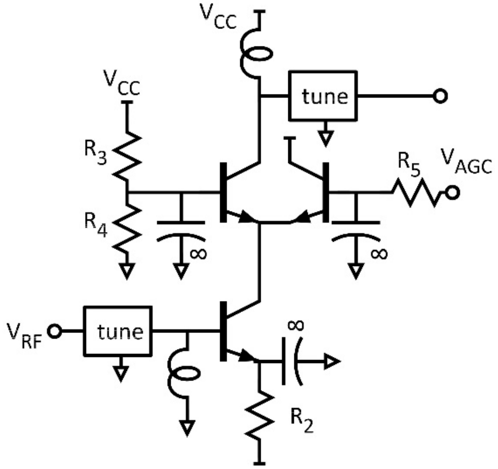
The top circuit is complex
but has stable DC bias



The middle circuit is less complex
but bias currents vary strongly with β.

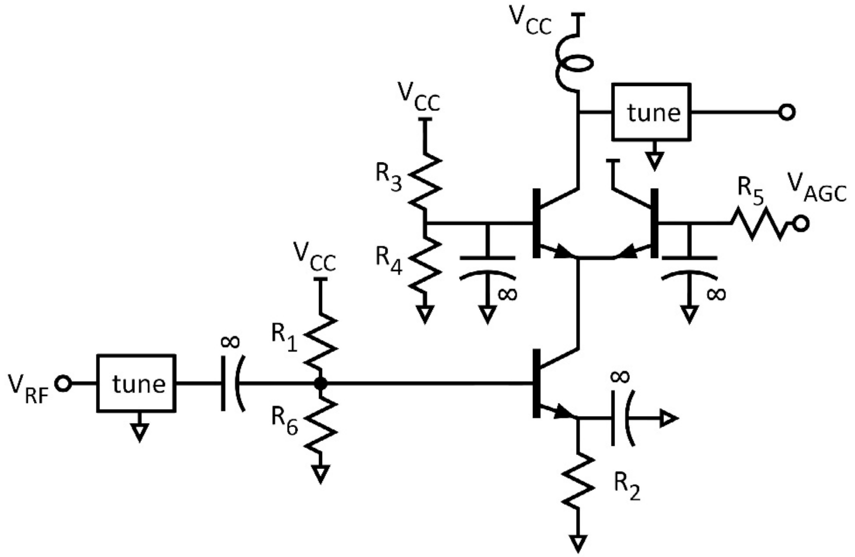


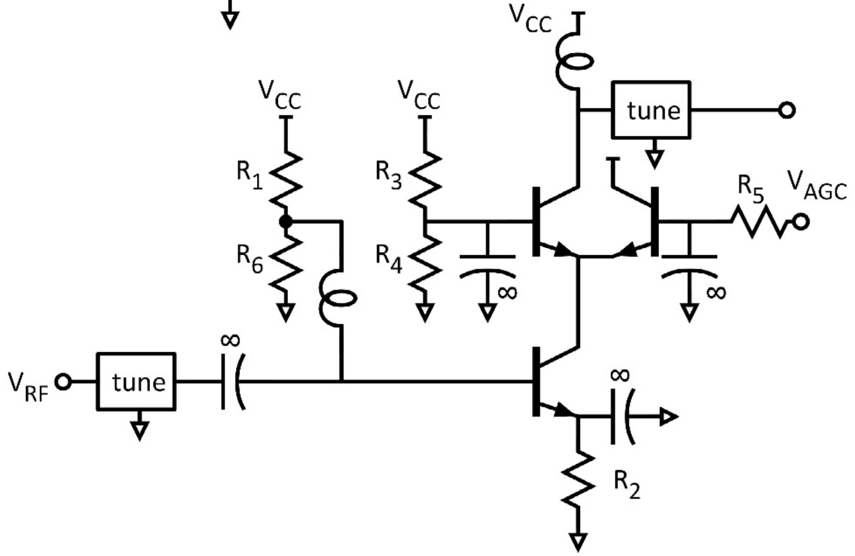
The bottom circuit has stable DC bias,
and has clean RF layout parasitics
(with micro-X bjt packages),
but requires + and - supplies.



Simpler variable-gain amplifiers

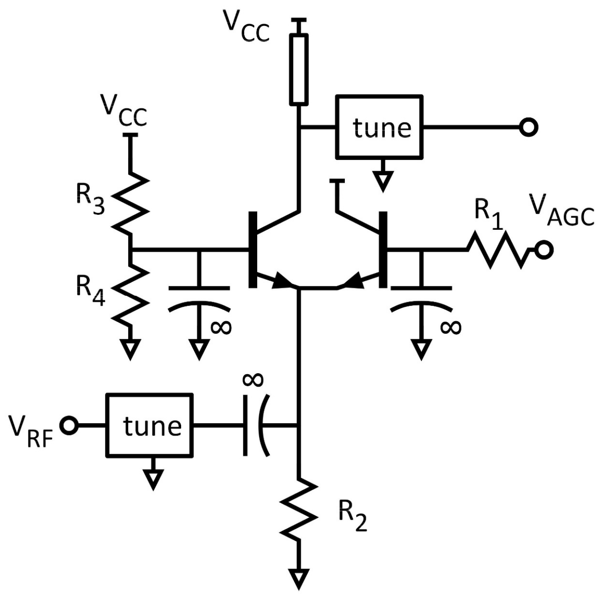
Two more single-supply options...



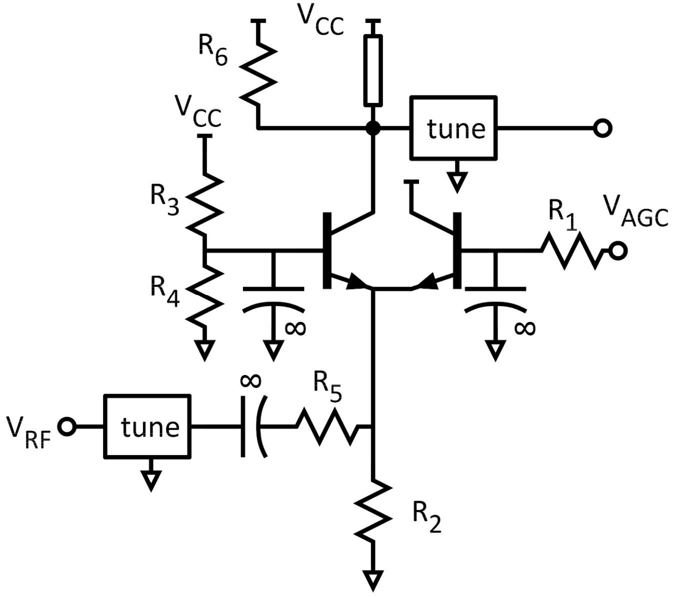


Even simpler variable-gain amplifiers

This is a common-base stage
with a variable-current shunt



By adding R_5 and R_6 , the input and output networks become lossy matching networks.



Lower gain, higher noise figure
broader bandwidth
easier matching network design