Today Week 5: Op Amps & their Golden Rules Mon Feb 24 H&H L8&9

…only 1 analog week left: next week you get your Arduino; start drafting your project

Required prep: you "must" skim H&H 163-206,

FOCUSSING ON Labs 8-1 to 5, 9-1a, -2, -3, & either -5 or -6, & -7.

Op Amps & their Golden Rules:

hi-gain diff amp; use w/negative feedback.

an active 3-terminal IC device, in an 8 pin DIP package, beware of hidden terminals!
typical op amp voltage gain > 10,000 + all biasing already done for you!
= an impedance matcher, values & gains determined only by external resistors.
dc operating "sweet" spot already set for you!

±15v rails, op amp sitting "virtually" at ground; feedback fights furiously maintaining it
no C_{input} or C_{output} blocking needed to maintain DC bias!

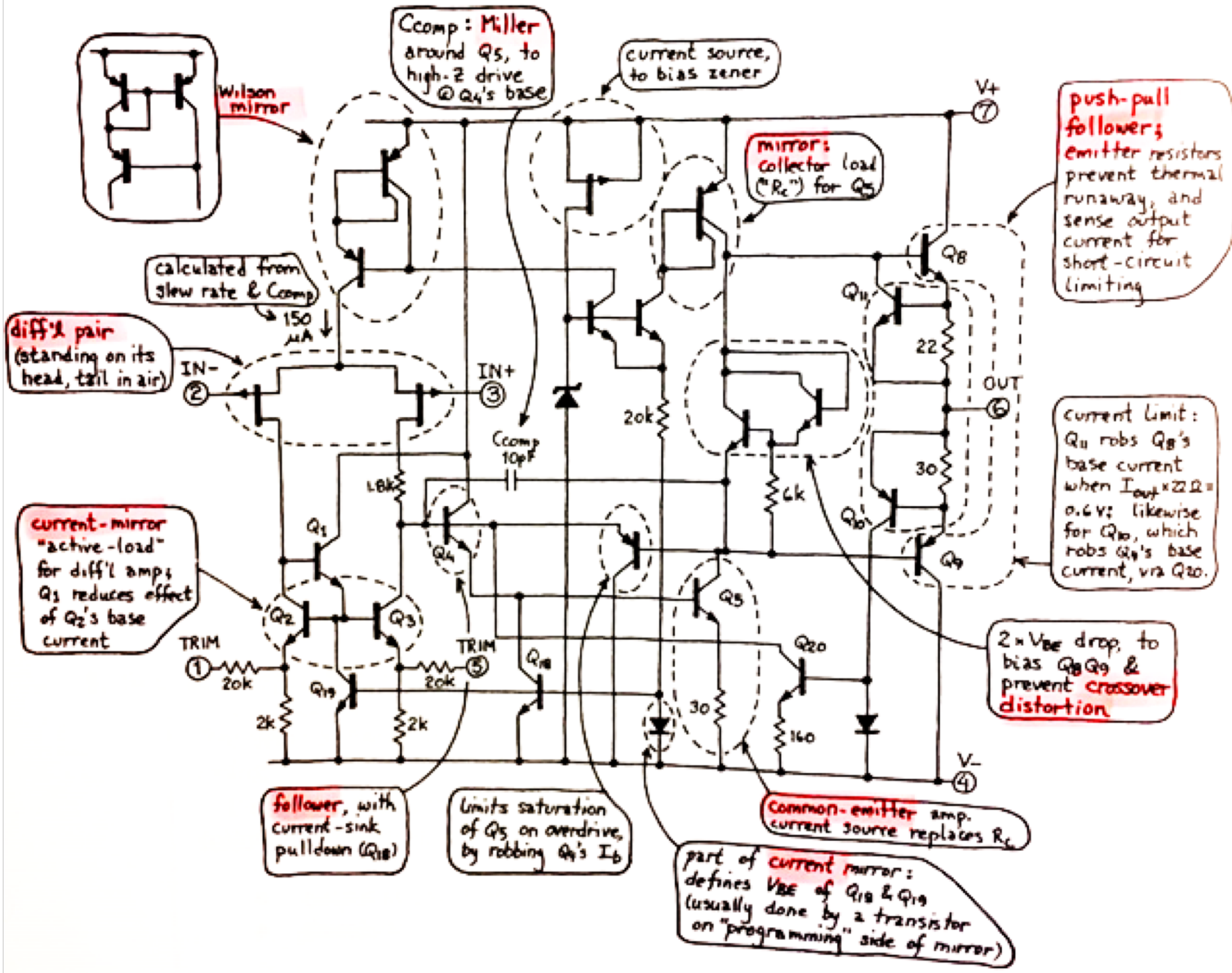
Constant gain up to HF…megaHz…temperature independent, highly linear.

Dynamic output voltage range (compliance) =symmetric saturation at the 2 rails.
Linear, no distortion, up to slew rate ~5 v/μsec, *i.e.* works up to MHz, not just audio.
Input dynamic range limited by hi gain. Peak inside: p. 232 op-Amp innards.

Extra pinouts: leave floating (manufacturer's testing, trimming, sorting; don't reverse!

…you're graduating from audio to hi-speed engineer (not yet ultra hi- (nano or giga))

LF411
OpAmp


Wilson mirror
Ccomp: Miller around Q5, to high-Z drive @ Q4's base
current source, to bias zener
V+
7
mirror: collector load ("Rc") for Q5
push-pull follower; emitter resistors prevent thermal runaway, and sense output current for short-circuit limiting
Q8
Q11
22
OUT
6
calculated from slew rate & Ccomp
150 µA
diff'l pair (standing on its head, tail in air)
IN-
2
IN+
3
20k
Ccomp 10pF
L8k
Q1
Q4
6k
30
Q10
Q9
current-mirror "active-load" for diff'l amp; Q1 reduces effect of Q2's base current
current limit: Q11 robs Q8's base current when Iout×22Ω = 0.6 V; likewise for Q10, which robs Q9's base current, via Q20.
Q2
Q3
Q5
Q20
TRIM
1
20k
TRIM
5
20k
Q18
2k
Q19
2k
30
160
2×VBE drop, to bias Q8 Q9 & prevent crossover distortion
V-
4
follower, with current-sink pulldown (Q18)
limits saturation of Q5 on overdrive, by robbing Q5's IB
common-emitter amp. current source replaces Rc
part of current mirror: defines VBE of Q18 & Q19 (usually done by a transistor on "programming" side of mirror)

Op amps work, if & only if you have negative feedback.

2 Golden “ideal” Rules (each with important limitations):

1) input voltage diff = 0 v,

2) input current +- to either + or – input = 0 ma

2 classic configurations: inverting & non-inverting,

Modified in innumerable ways with non-linear “hair” around them.

2 resistor (linear, non-active) ratio determines gain

Hi input Z, low output Z, gain > 10,000

.

Next Monday, Mar 2, “must” skimming H&H 207-231,

Last analog lab: Schmidt trigger; FET switches

DVM *vs* VOM *vs* x10 Scopeprobe

DVM...10 MΩ input impedance...a FET input stage (hi-Z, followed by an op amp).

do not use VOM...much too low impedance, 20 kΩ/v...& variable

Beware of body resistance, ~1MΩ, *e.g.* don't short out a 10 MΩ component by touch

Scopespersonship: "Thou shalt compensate thy probe!"

Scope input impedance = 1 MΩ, too low for ultra-hi input impedance op amps.

With x10 probe, R & C impedance = 10MΩ & 10pf…can work up to MHz,

but must select on scope "probe x10",

...probe/scope an RC circuit, must trim probe C to present same Z at all frequencies.

...use scope "compensator" output, a 5v, 1 kHz square wave, special Fourier xform:

Edge of square wave edge = "theta" function, has equally all frequencies (like a δ-function)

Vary probe C with non-conducting screwdriver (in your wire box) until waveform is square,

no extra C, no extra inductance L

Impedances of an Op Amp...how to measure

Treat Op Amp as a Thevenin black box: a V_{th} in series with R_{th}

R_{in}: looking into the input terminal

R_{out}: looking into output terminal

Measure open circuit V, $= V_{th}$.

Add variable R in series (substitution box most convenient)

Change R until V across it is = ½ V_{th}

$R_{th} = R$

Mon, Mar 16, 1st after break:

DIGITAL ELECTRONICS: gates, binary logic, NANDs, Flip Flops, logic probes…

During Spring Break...

Skim H&H 281-341, focus on L13 & 14, and

Prepare for Labs 13-1, 2, 4, 5, but not TTL (Transistor-Transistor Logic +5v/0v)

Labs 14-1, 2, 5-b. vs. ECL (Emitter-Coupled Logic, push-pull)

Play with your Arduino microprocessor & cable at home; MUST bring laptop to lab.

Read Eric Hazen's page for the minimal C you must know:
https://docs.google.com/document/d/1dNcLgDqVa4kXvEaW8MCvMPSsF3m3jEKtGxN8k60e8-o/edit

Follow Dan Gastler's "Crash Course in C" lecture slides:
https://docs.google.com/presentation/d/18sV6cQqeDFwiH5KBWFixevLTHqkzHcVgzM-WMMHFghs/edit?usp=sharing

Download Arduino software to your laptop; do the "blink" tutorial at
http://arduino.cc/en/Tutorial/Foundations

REVIEW FOR WRITTEN MIDTERM ON ANALOG ELECTRONICS:

1) your log books
2) circuits you've constructed
3) session summaries…on eLab webpage