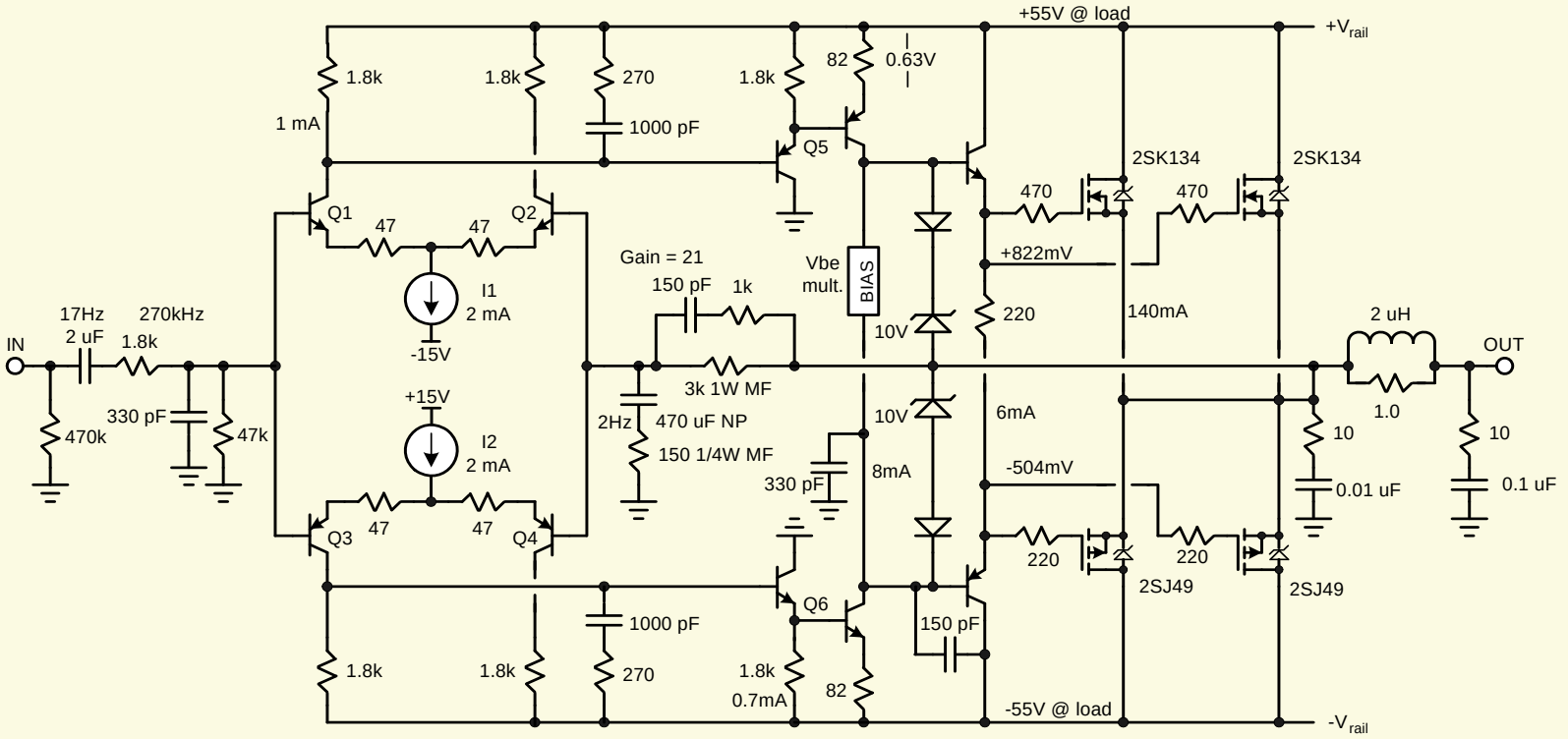
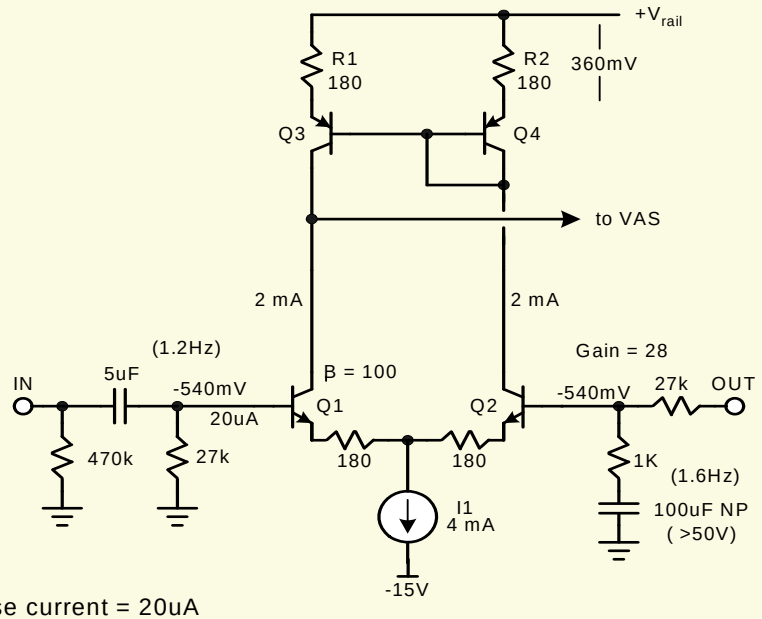
The DH-220C Audio Amplifier Design

- The Hafler DH-220
- N-channel JFET input stages
- DC servos and advantages
- Full complementary input stages and P-P VAS
- LSK489 and LSJ689 dual monolithic JFETs
- Bias spreader and gate protection
- Lateral MOSFET output stage & distortion
- DH-220C performance

Hafler DH220 (simplified)



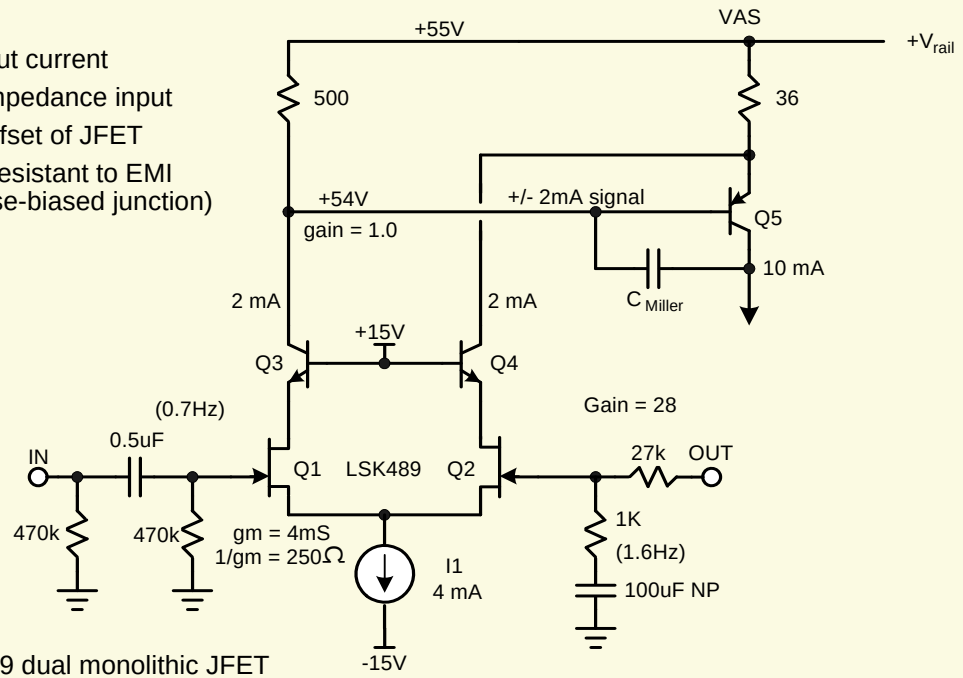
BJT Input Stage



- Base current = 20uA
- 10% β mismatch => 54mV input offset
- use dual monolithic BJT

Basic JFET Input Stage

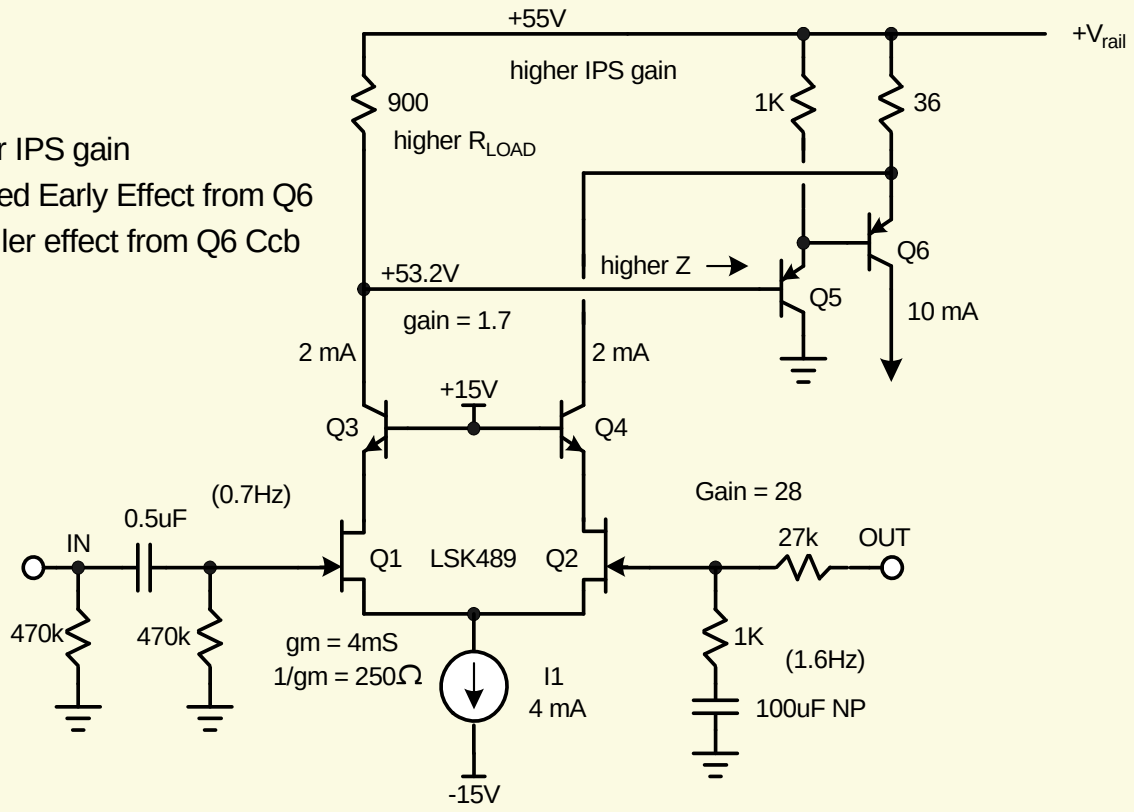
- no input current
- high impedance input
- only offset of JFET
- more resistant to EMI
  (reverse-biased junction)



- LSK489 dual monolithic JFET
- low dc offset
- low noise
- low capacitances: Ciss = 4pF, Crss = 2pF

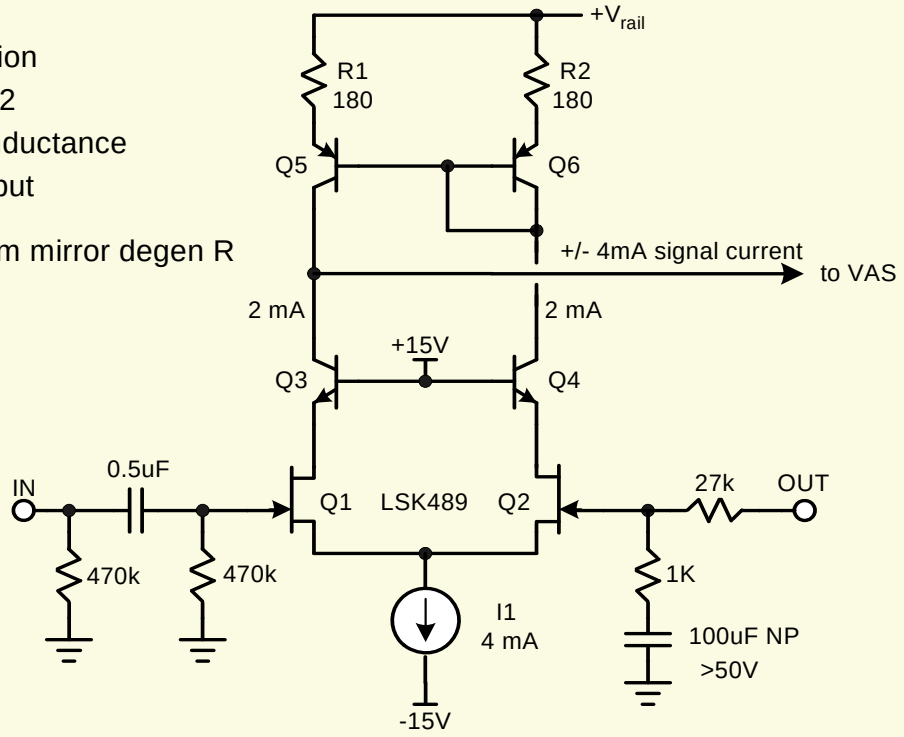
JFET IPS with 2EF VAS

- higher IPS gain
- reduced Early Effect from Q6
- no Miller effect from Q6 Ccb



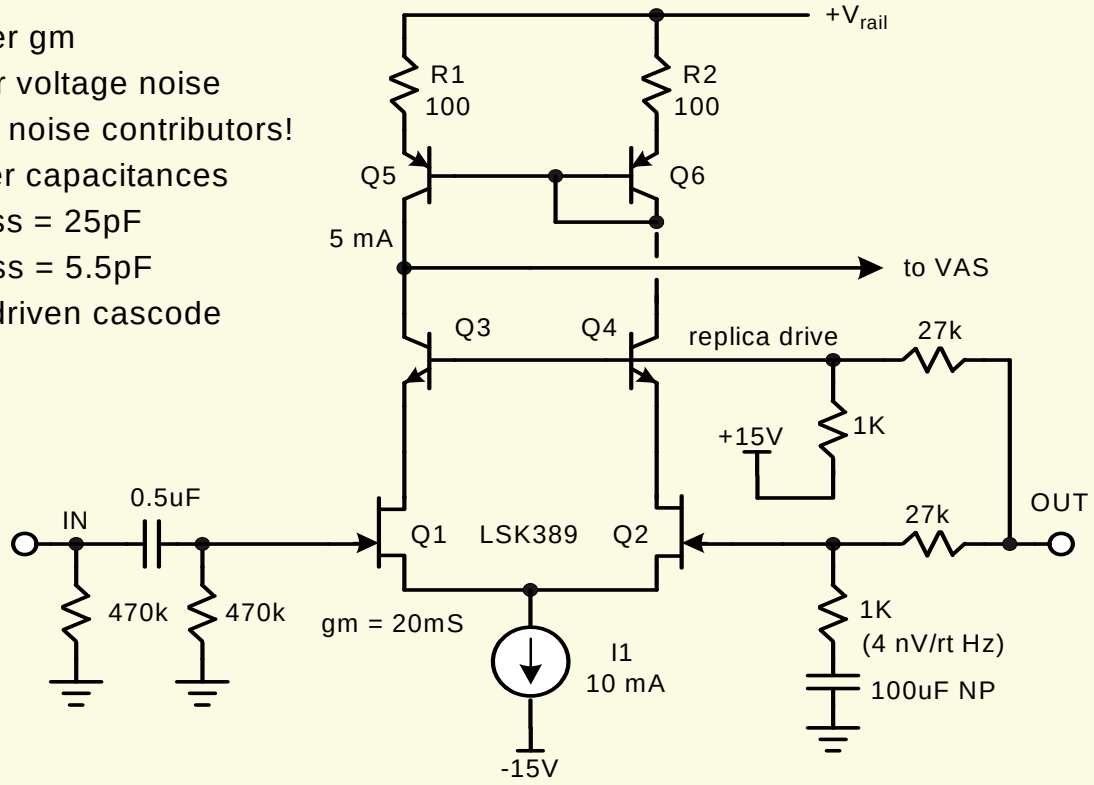
JFET IPS with Current Mirror

- very high Z IPS load
- common mode rejection
- Iq1 forced to equal Iq2
- doubles IPS transconductance
- doubles max IPS output signal current
- potential for noise from mirror degen R

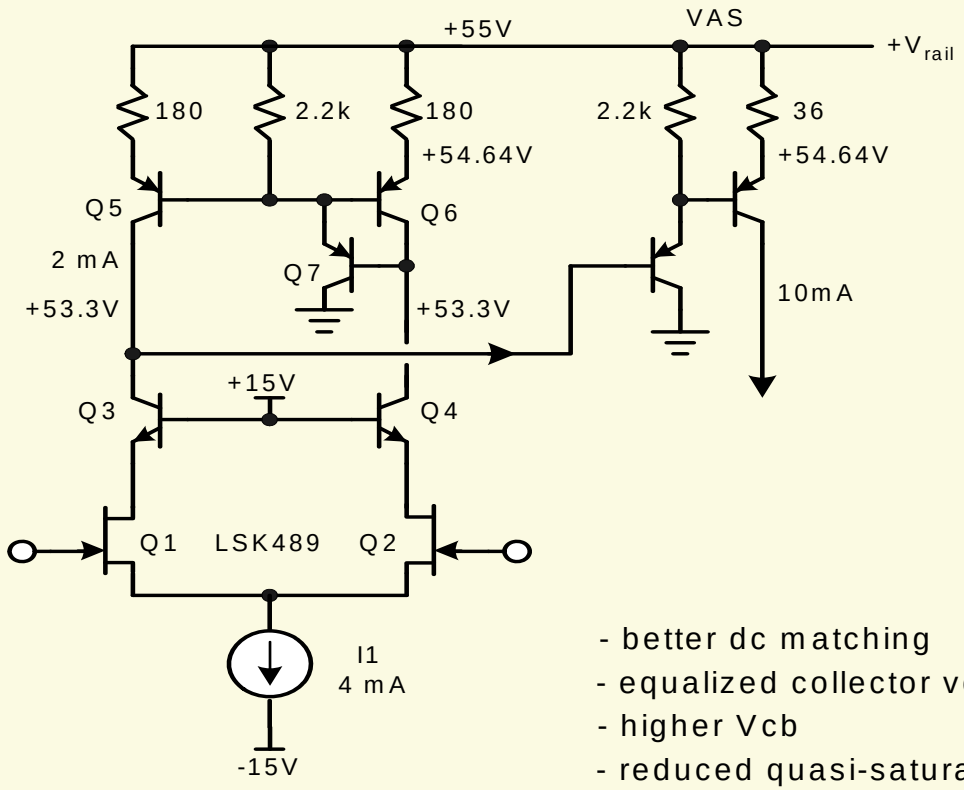


JFET IPS with LSK389

- higher gm
- lower voltage noise
- other noise contributors!
- higher capacitances
  - Ciss = 25pF
  - Crss = 5.5pF
- use driven cascode

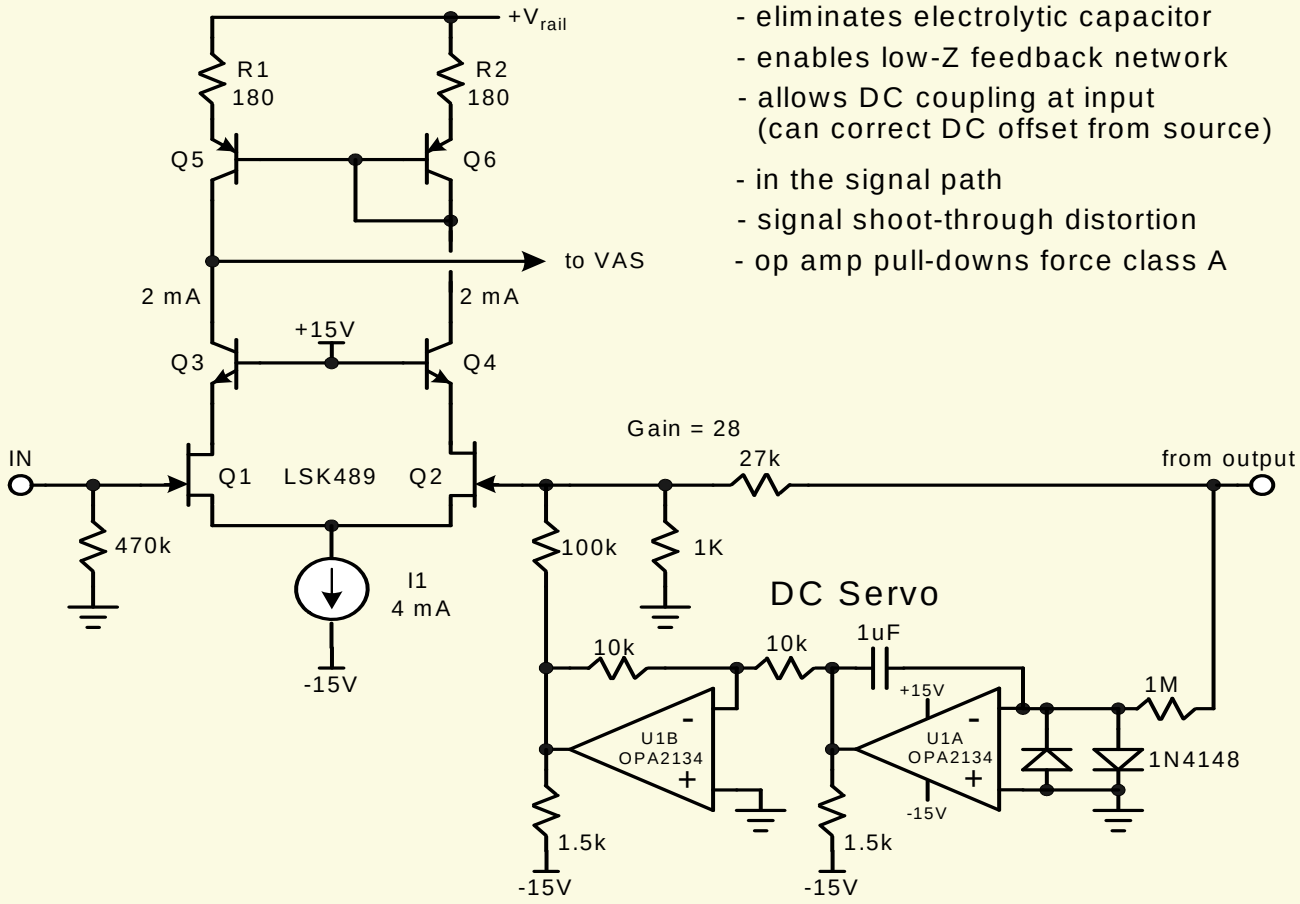


JFET IPS with Helpered Current Mirror



- better dc matching
- equalized collector voltages
- higher Vcb
- reduced quasi-saturation

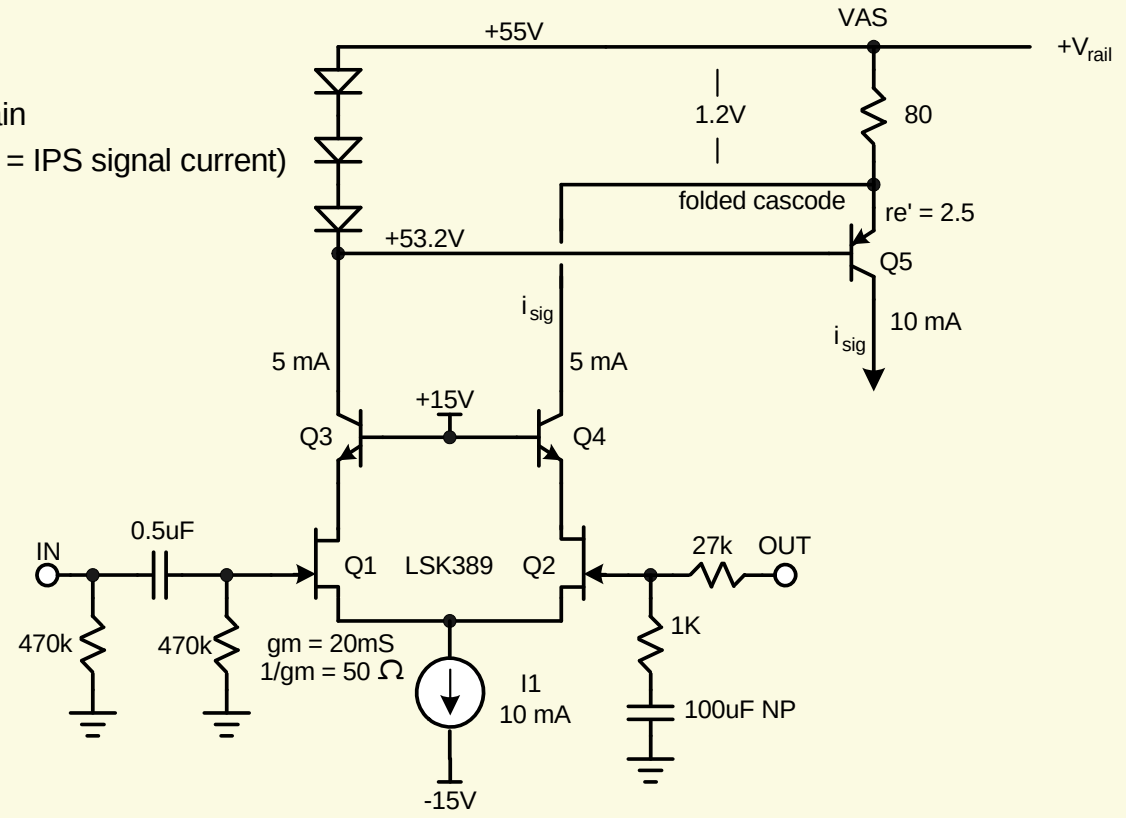
JFET IPS with DC Servo



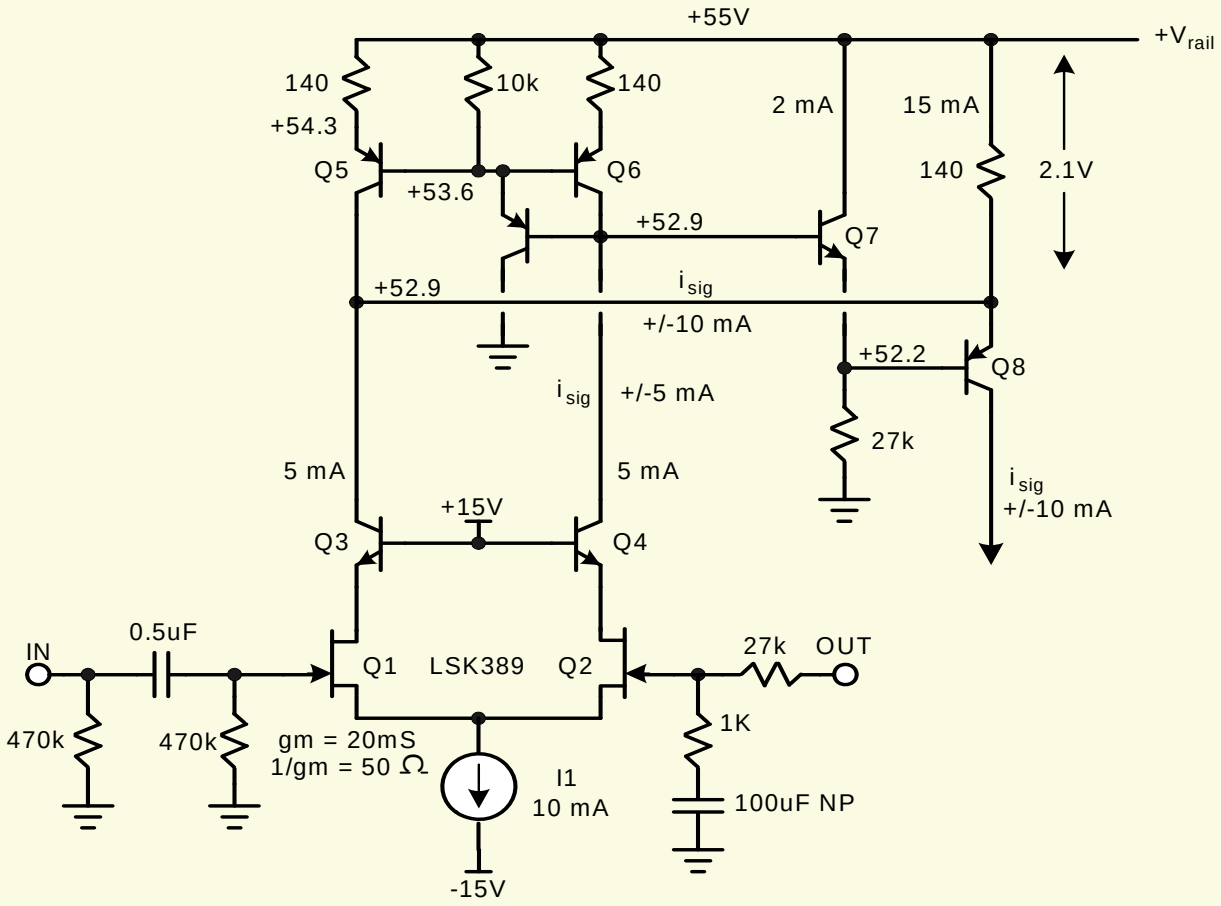
- eliminates electrolytic capacitor
- enables low-Z feedback network
- allows DC coupling at input
  (can correct DC offset from source)
- in the signal path
- signal shoot-through distortion
- op amp pull-downs force class A

JFET IPS Folded Cascode

- fast
- no signal current gain
  (VAS signal current = IPS signal current)
- watch noise



JFET IPS Folded Cascode with Imirror



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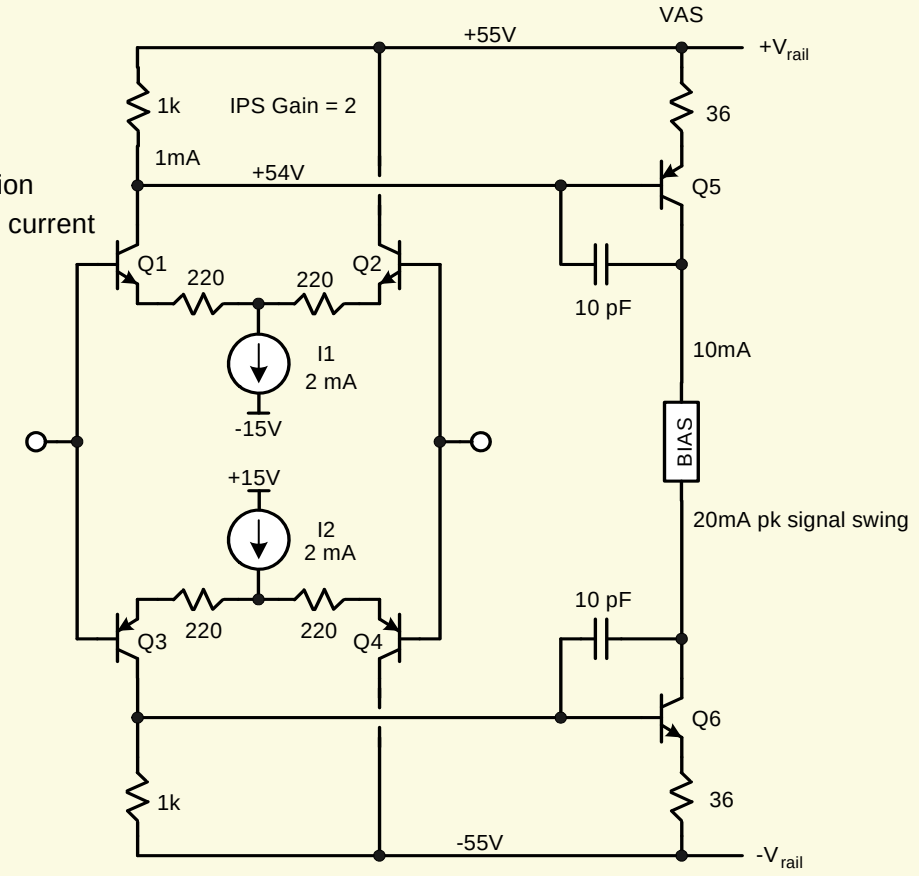
BJT Full Complementary IPS

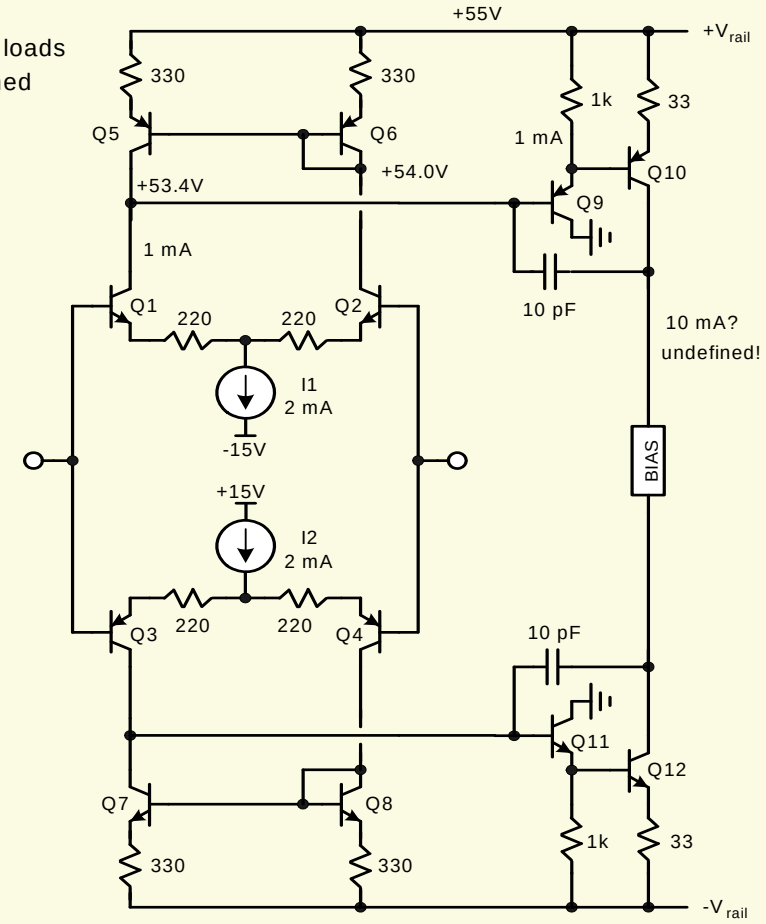
- enables push-pull VAS
- twice signal current output
- 3dB lower noise
- some input bias current cancellation
- VAS bias current sensitive to IPS current (S = 2.6:1)
- matching within pairs important

- Miller compensation
- ULGF = 1 MHz for CLG = 28
- ~100 V/us slew rate



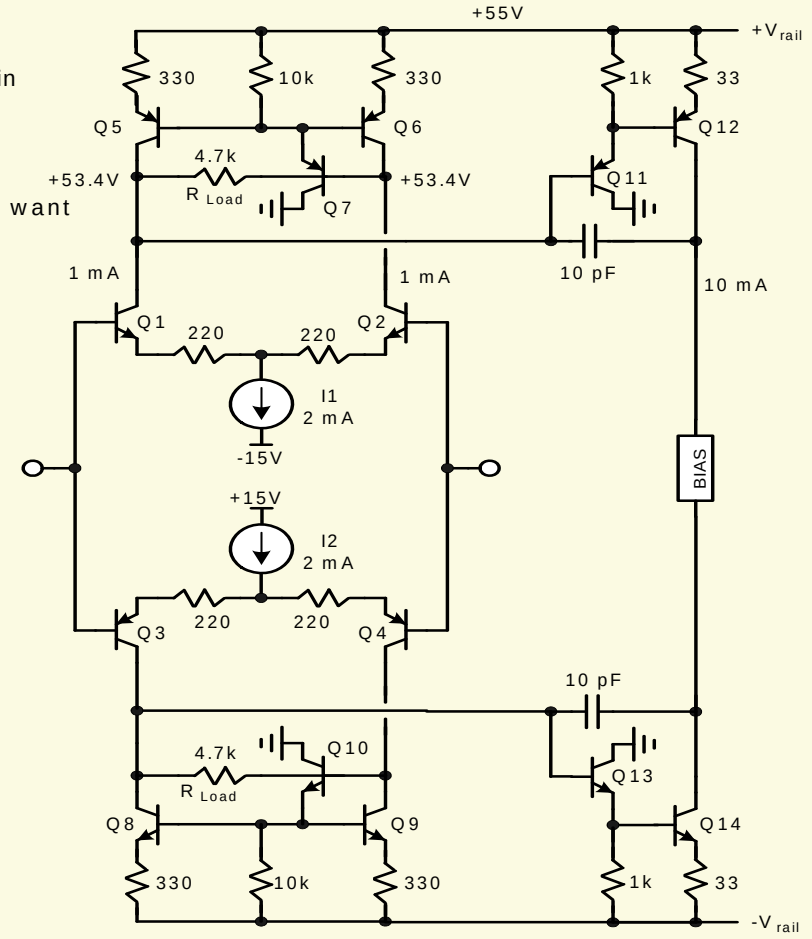
BJT Full Complementary IPS with Mirrors

- benefits of current mirror loads
- BUT VAS current undefined



Complementary IPS with Loaded Mirrors

- 0V across R_{Load}
- stabilized and defined IPS DC gain
- defined VAS operating current
- reduced loop gain at VLF
- but plenty of OLG in VAS
- choose R_{Load} to be whatever you want
- IPS gain = 10 (good)



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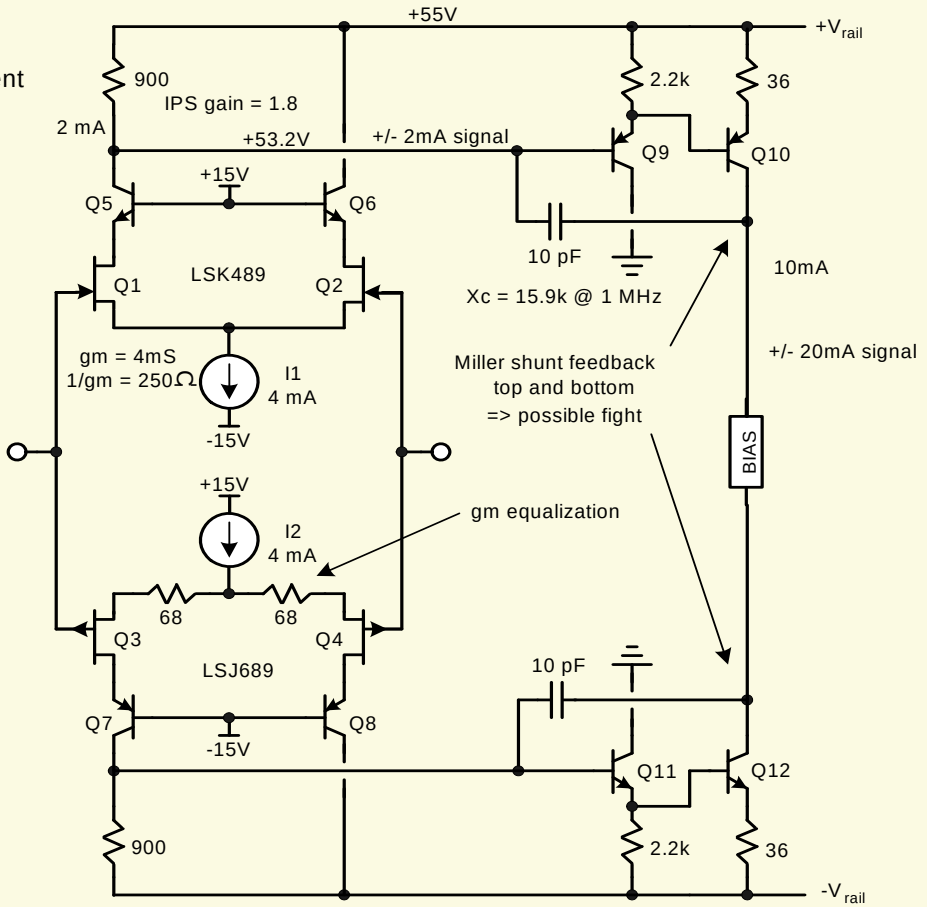
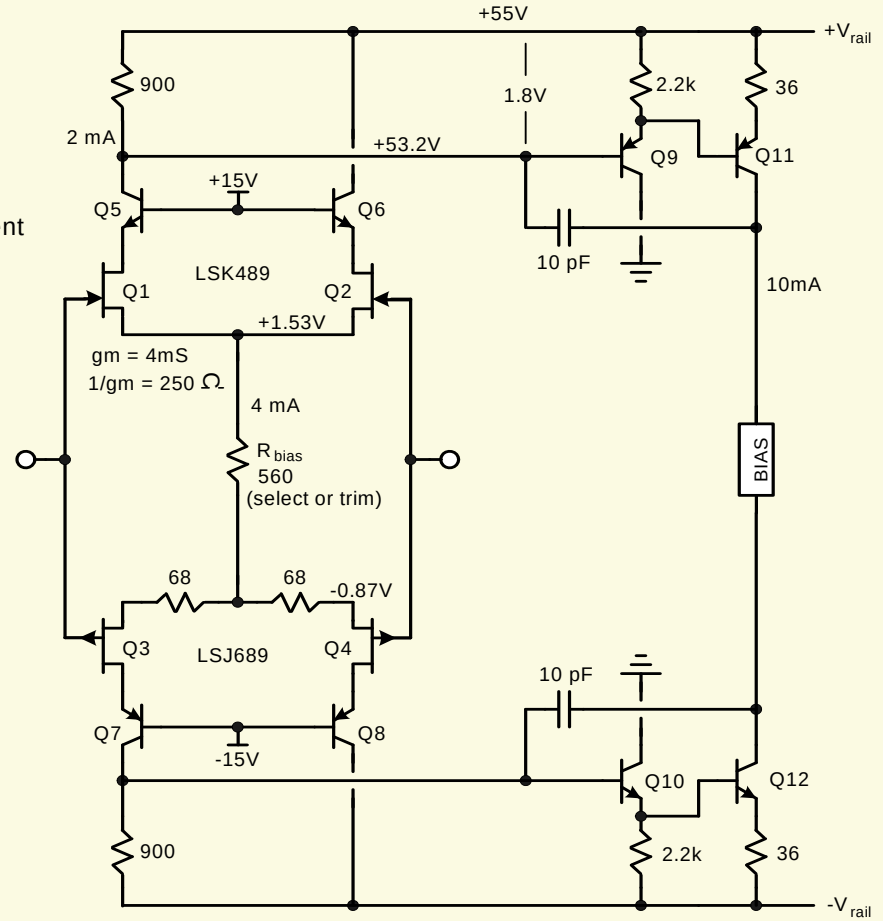
Complementary JFET IPS

- gm equalization desirable
- DC offset in each pair affects VAS current
- use dual monolithic JFETs
- ULGF = 1 MHz @ CLG = 28
- slew rate = 2mA/10pF = 200V/us



JFET IPS with Floating Tail

- simple elegant design
- dual monolithic JFETs desirable
- JFET pairs selected for sum of Vgs_on to control IPS current
- OR trim R_{bias}
- VAS current controlled by IPS current



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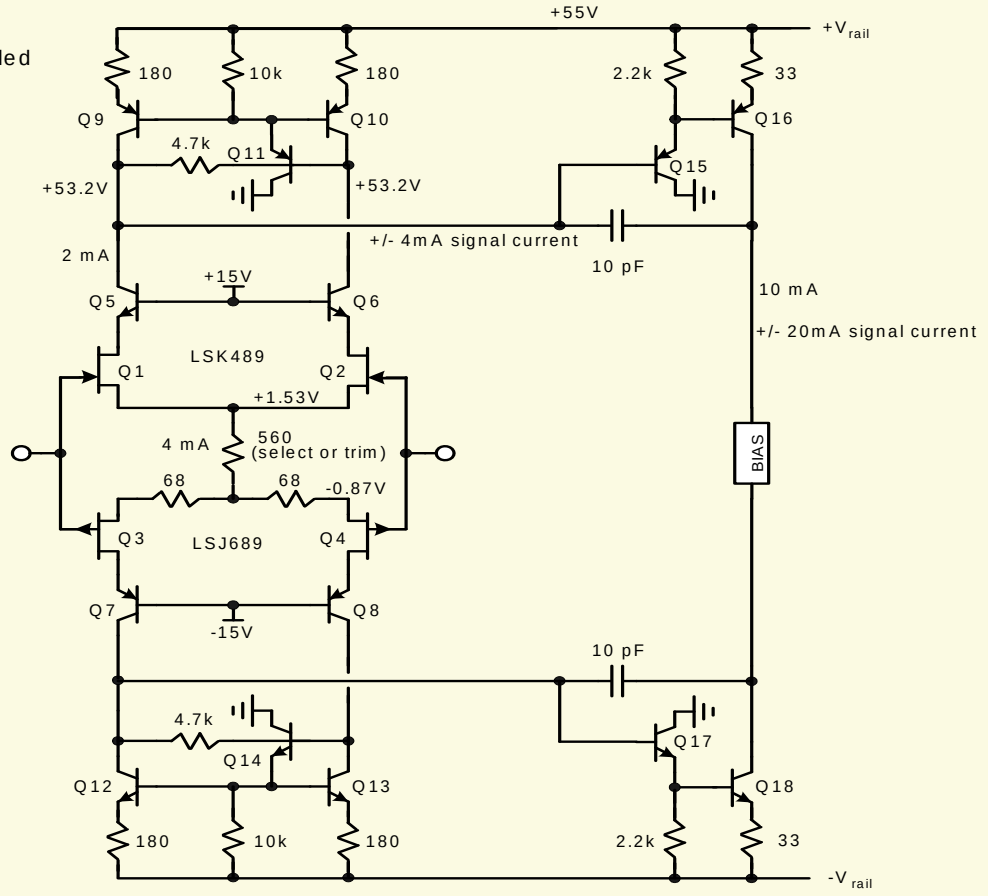
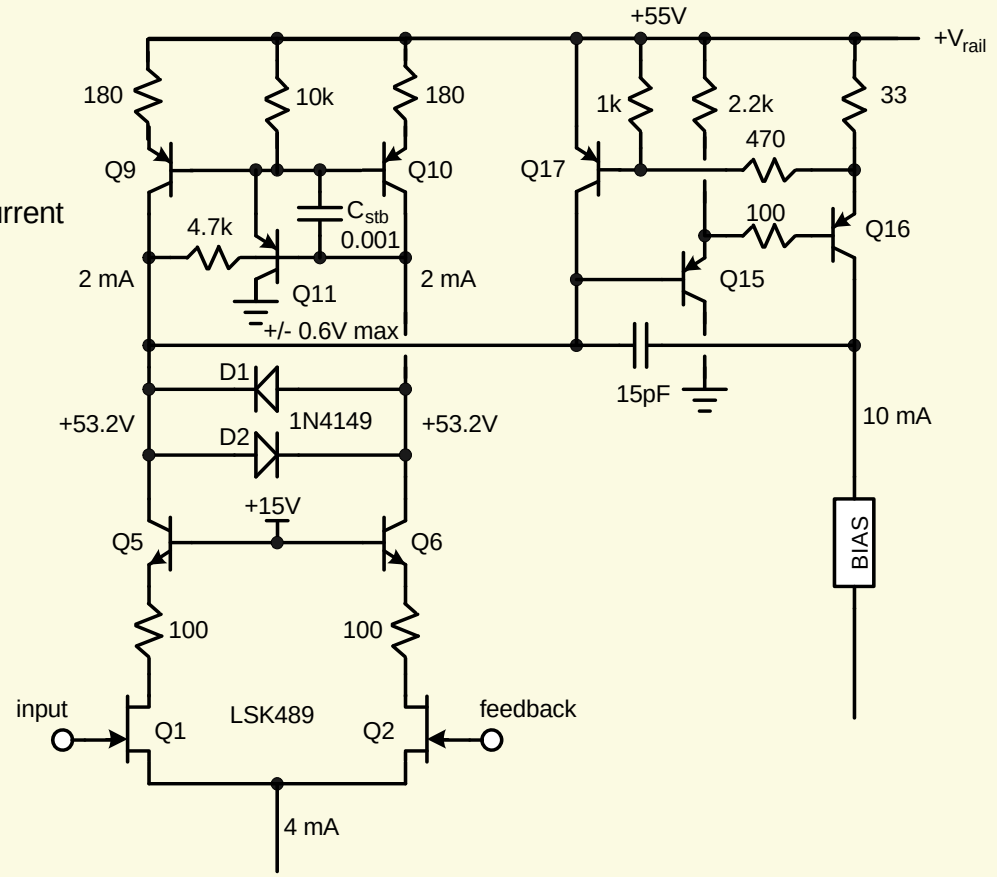
JFET IPS with Current Mirrors

- IPS transconductance doubled
- loaded current mirror



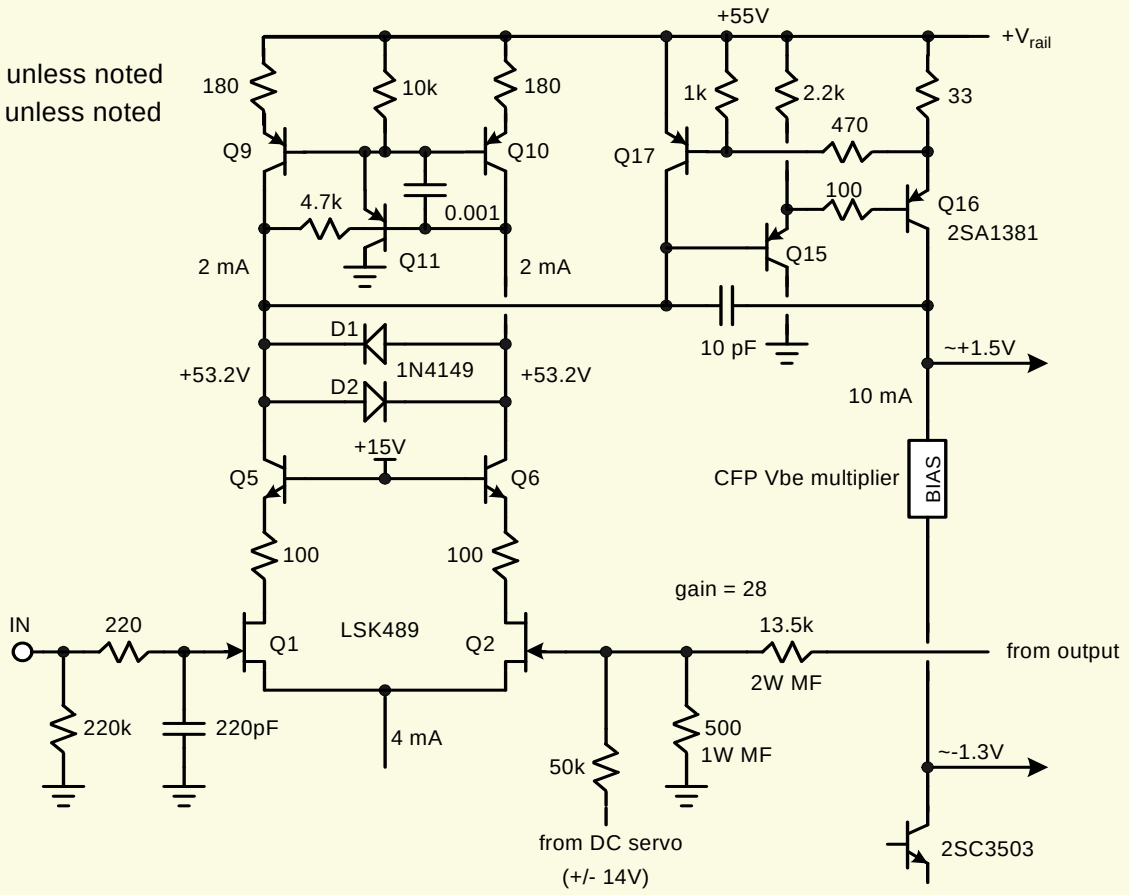
Clamped Current Mirror and VAS

- D1, D2 clamp IPS output swing
- controlled swing when clipping
- Q16 base resistor limits Q15 current
- C_{stb} helps VHF stability
- Q5, Q6 REs help VHF stability
- Q17 limits Q16 to 20mA

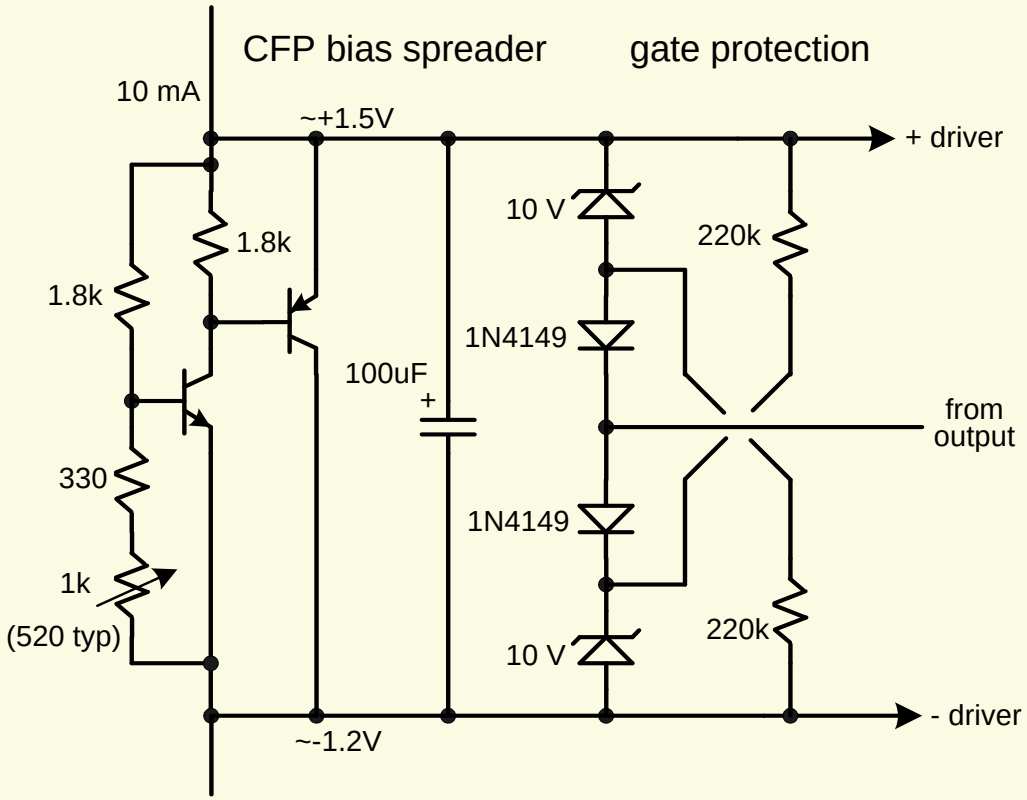


IPS and VAS (top half)

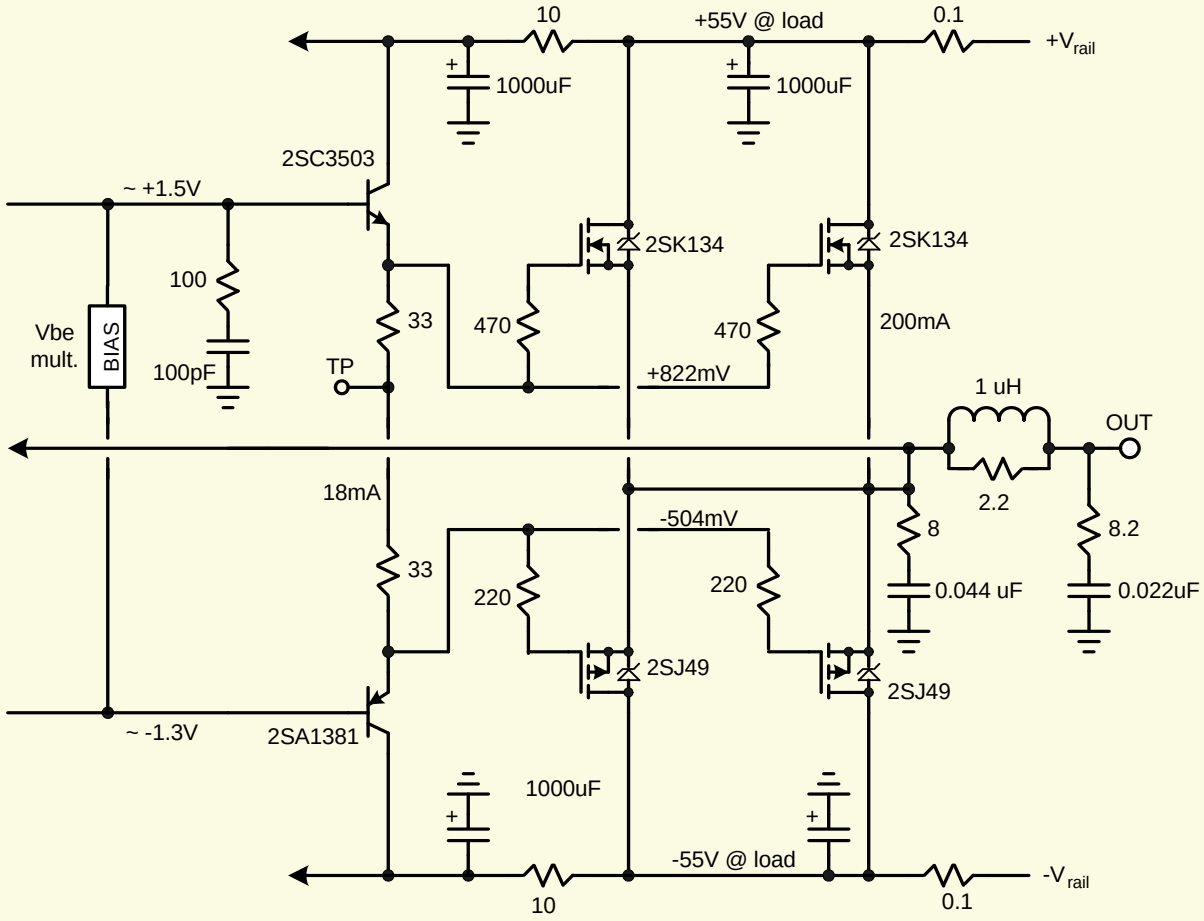
- all NPN 2N5551 unless noted
- all PNP 2N5401 unless noted



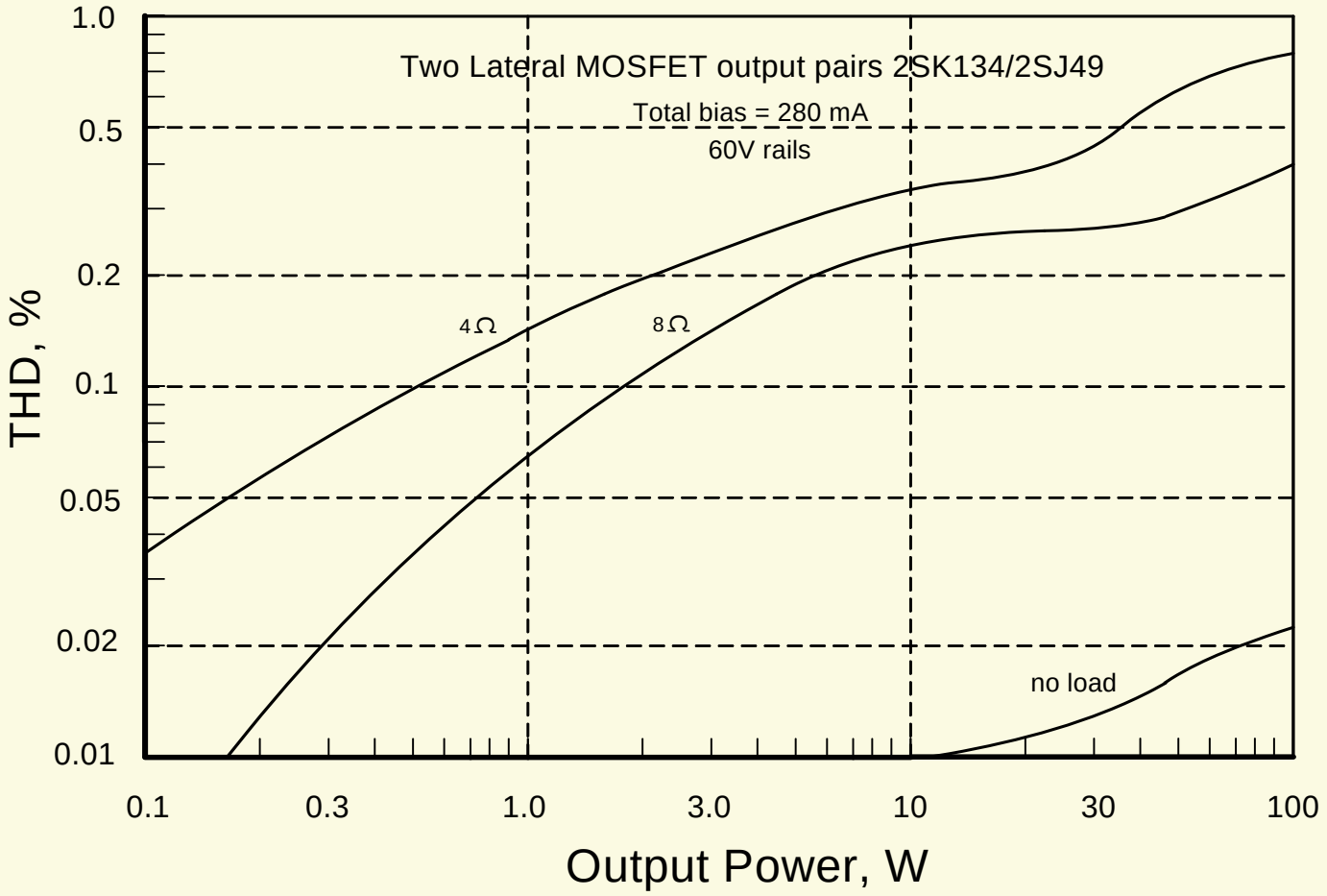
Bias Spreader and Gate Protection



Output Stage



Lateral MOSFET OPS THD-1



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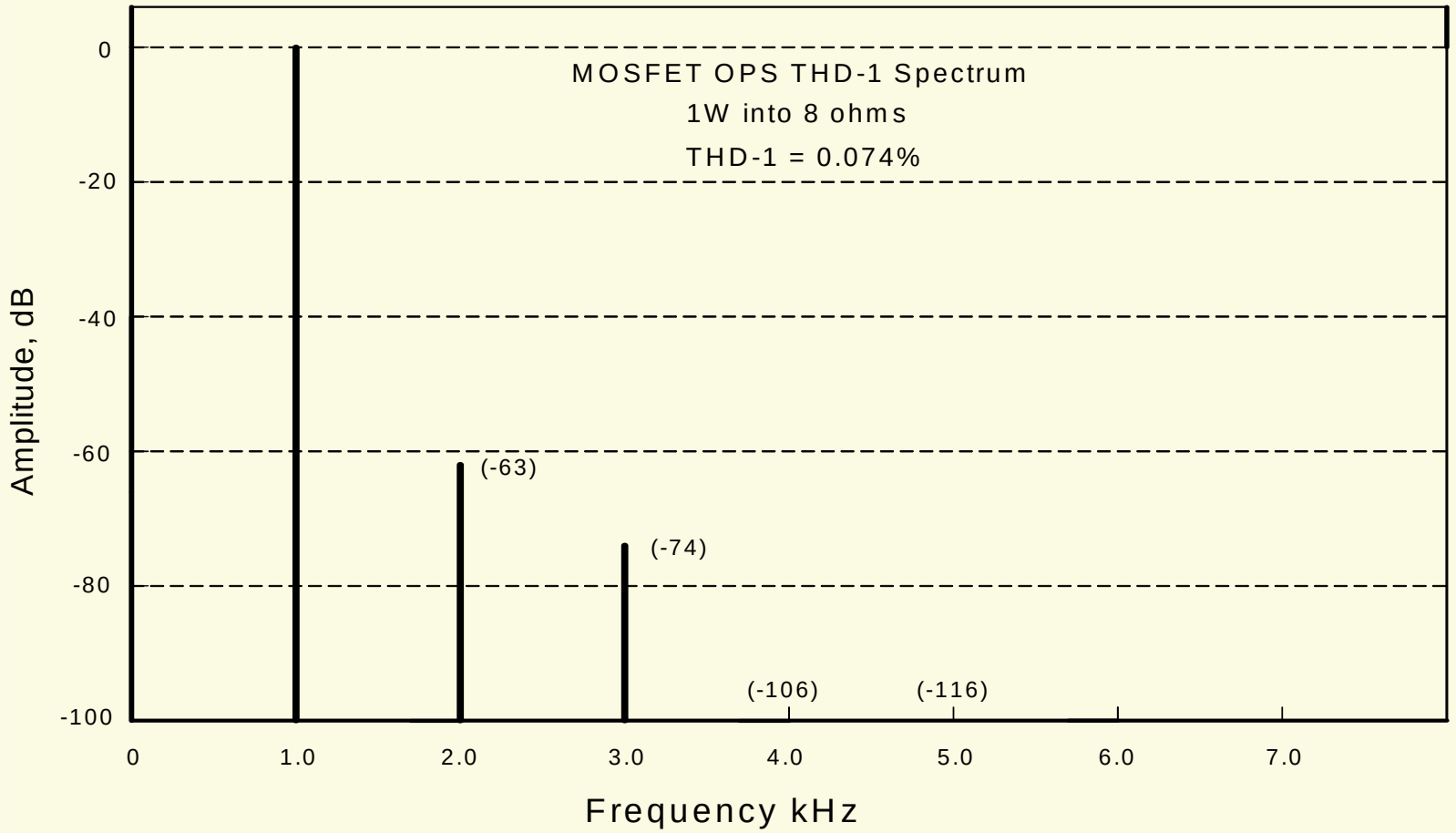
MOSFET OPS THD-1 Spectrum @ 1W



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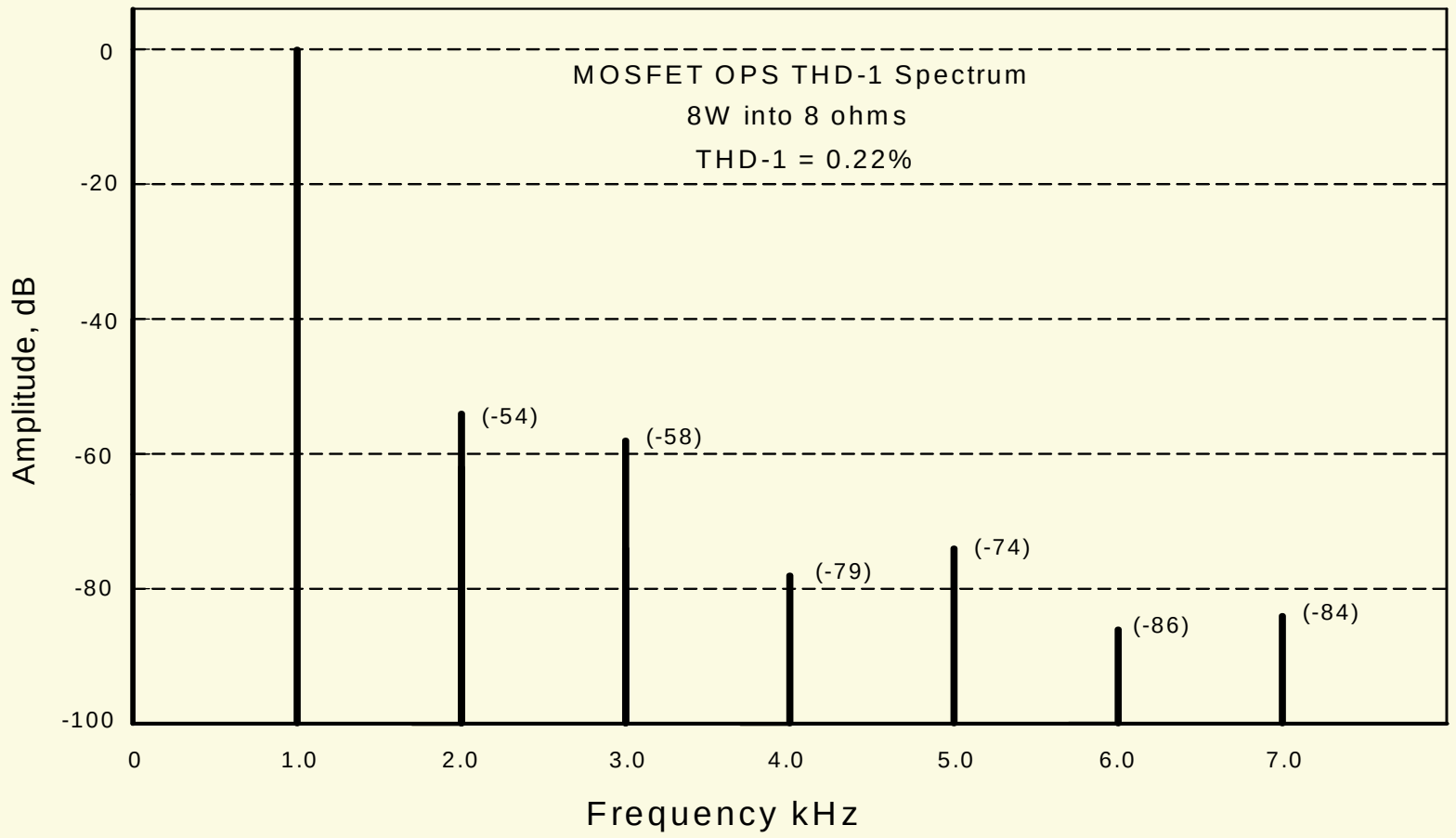
MOSFET OPS THD-1 Spectrum @ 8W



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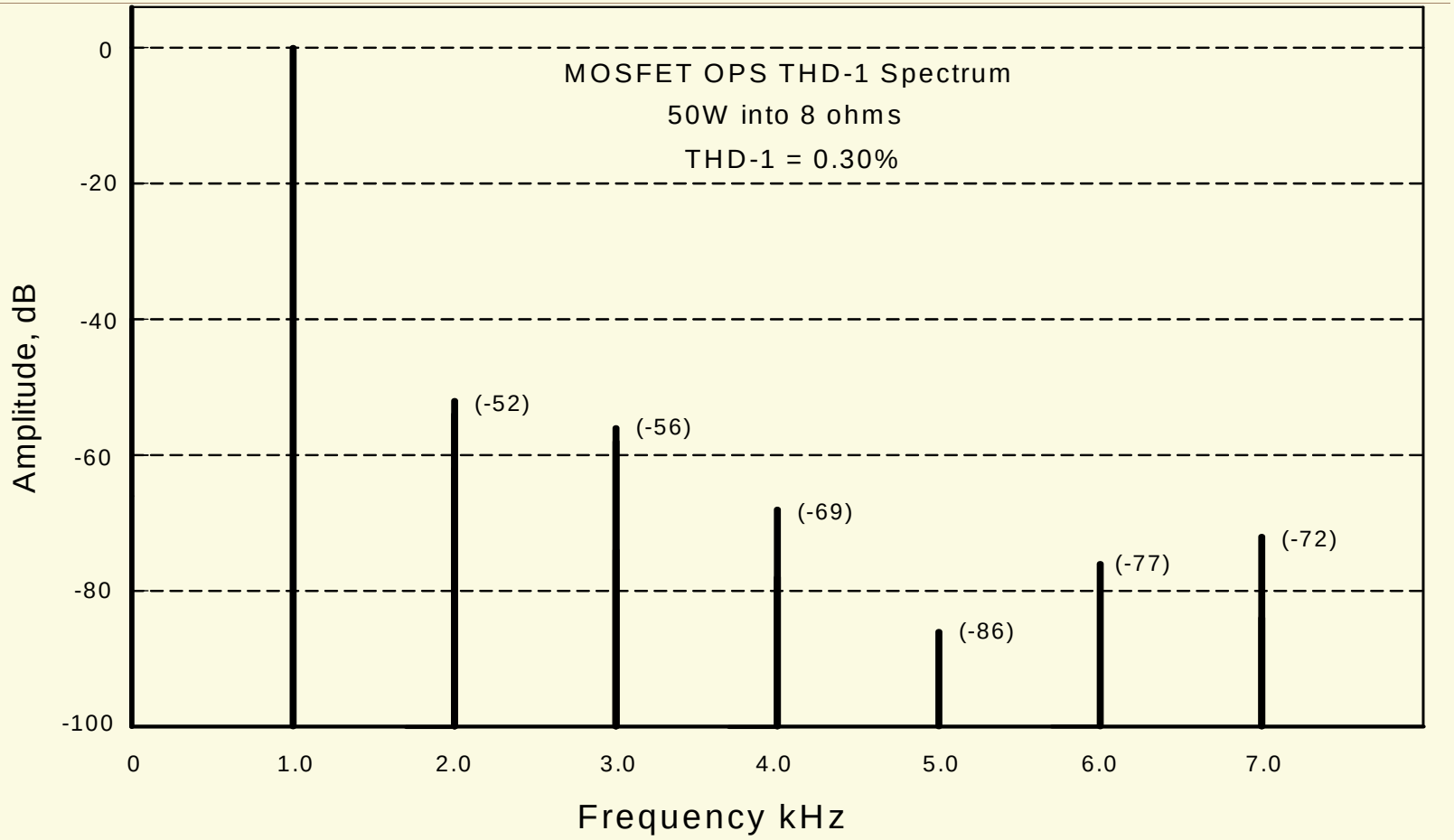
MOSFET OPS THD-1 Spectrum @ 50W



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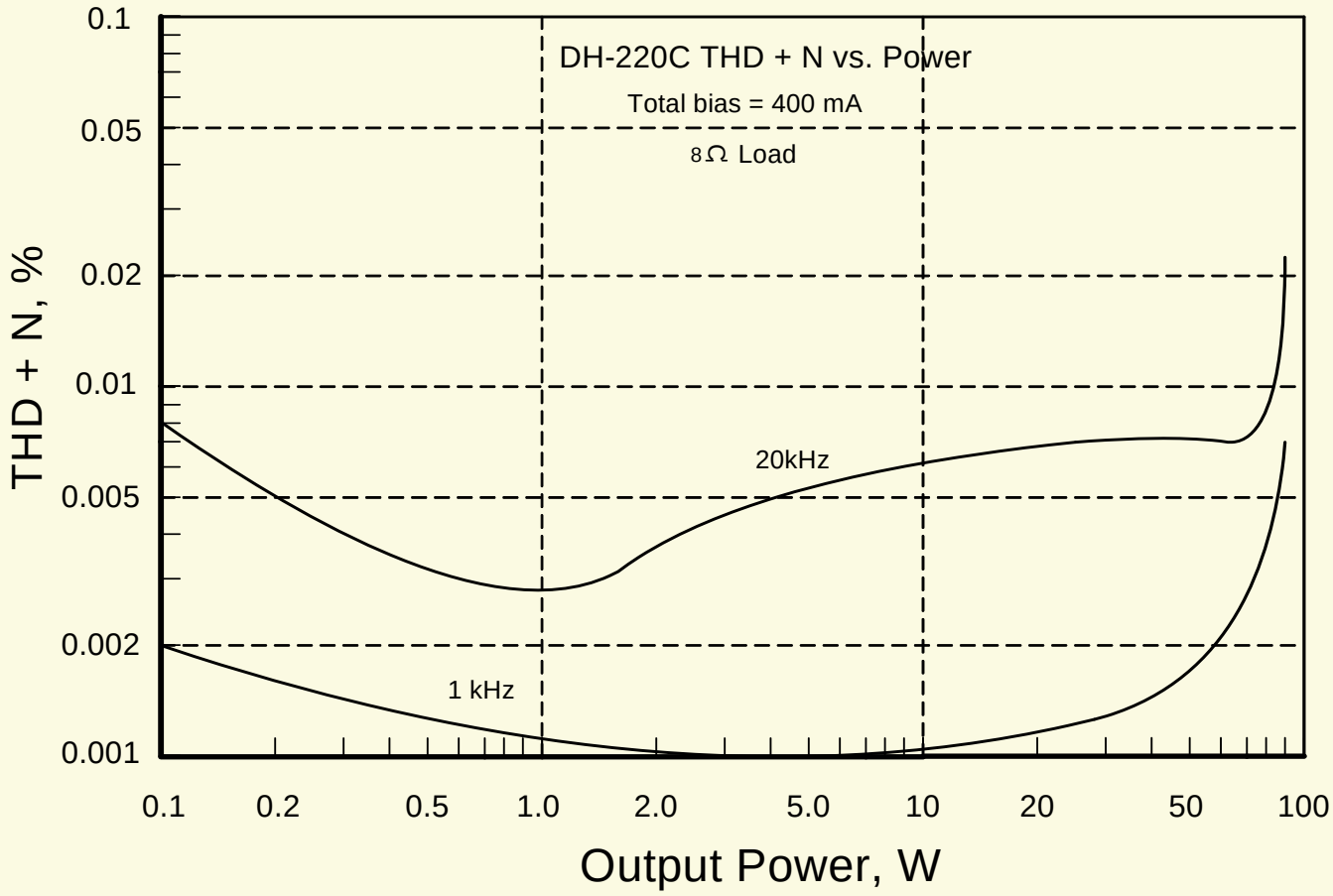
DH-220C THD + N vs Power



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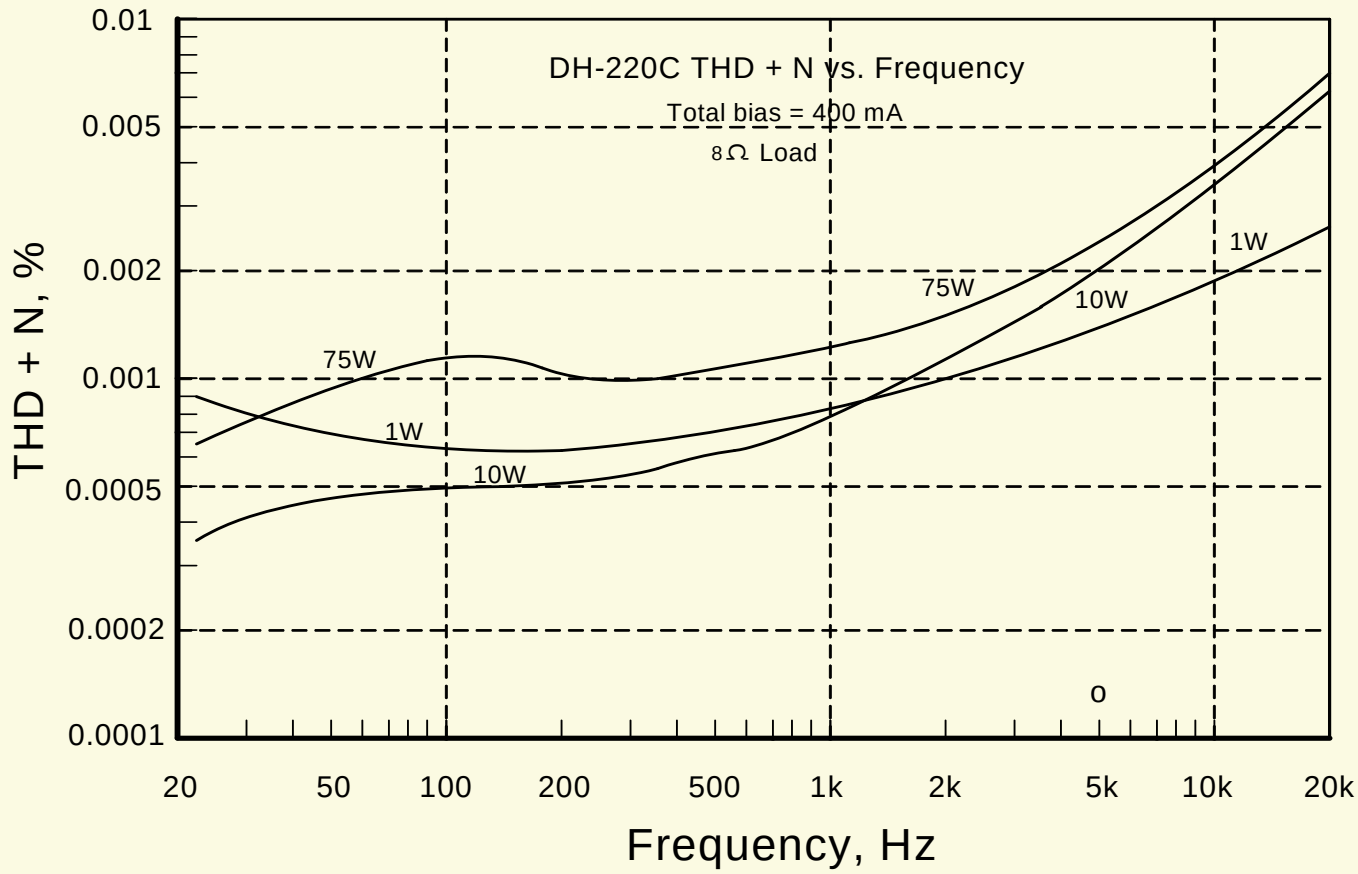
DH-220C THD + N vs Frequency



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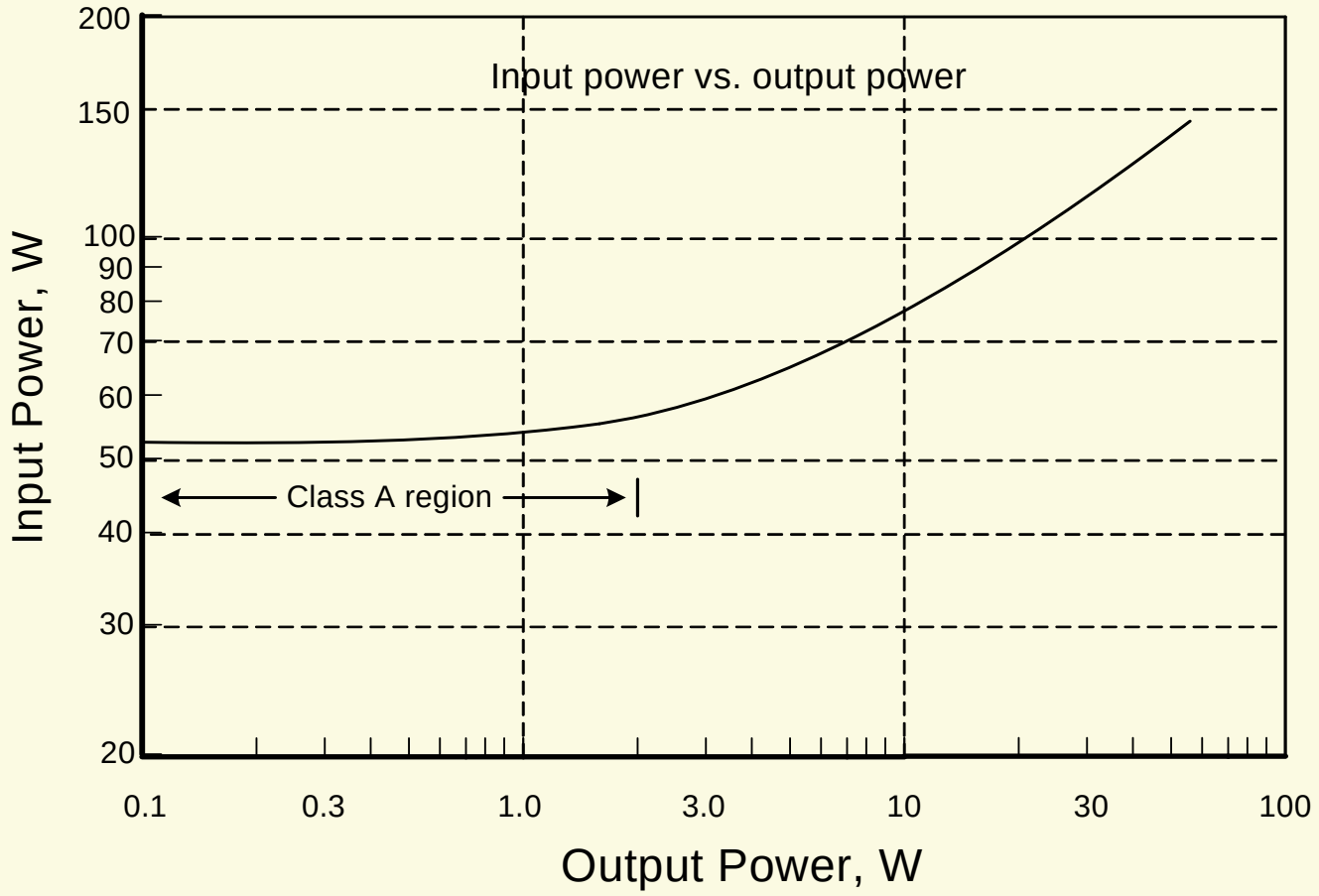
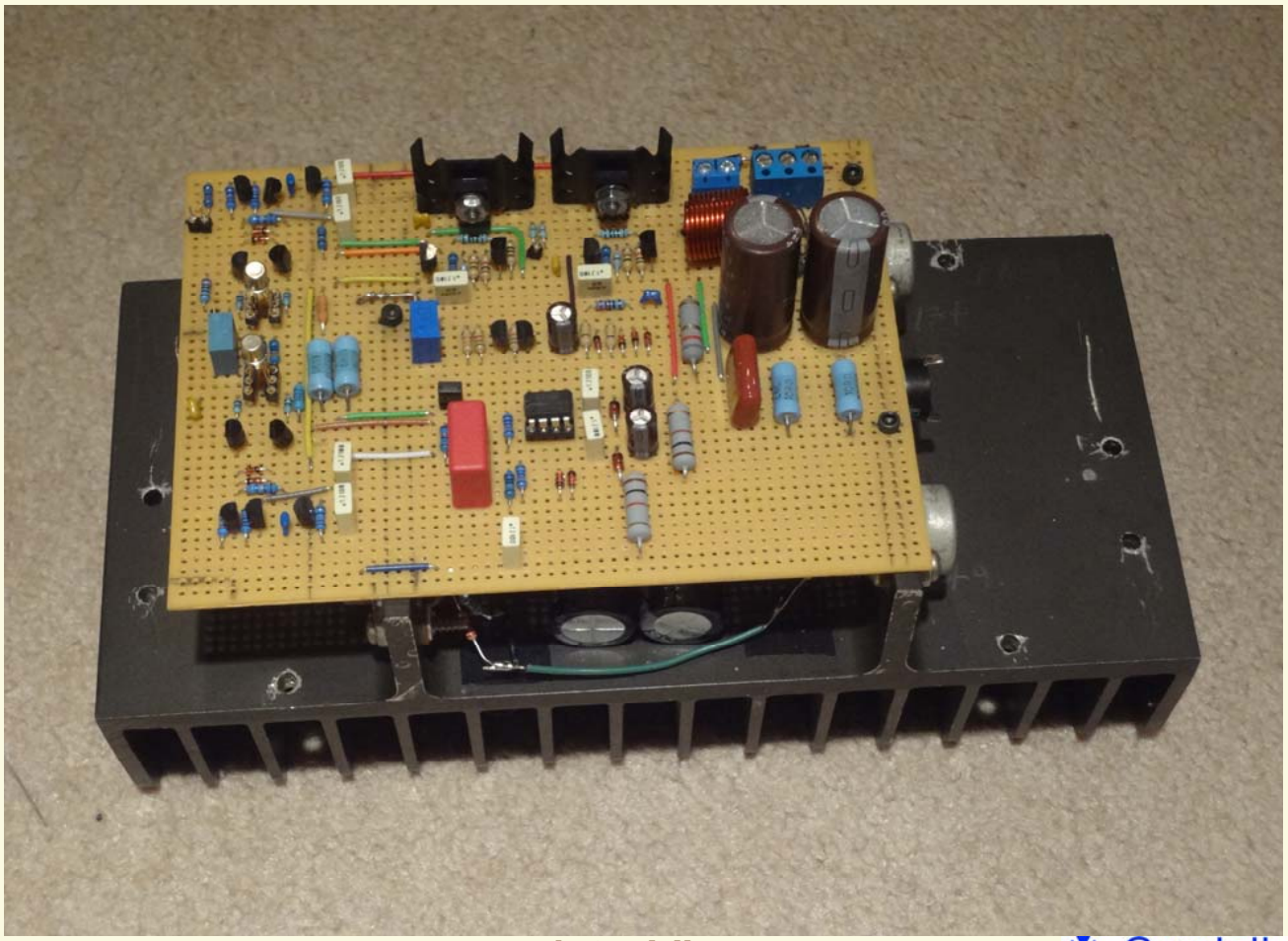
Input Power vs Output Power



Performance

- Very low THD-1 and THD-20
- THD-1+N 0.001% @ 2w, 8 ohms
- THD-20+N 0.007% @ 75w, 8 ohms
- Very low noise – 5 nV/rt Hz
- 104 dB A wtd S/N re 1w, 8 ohms
- Large class A region – 400mA bias

The DH-220C Breadboard



Summary

- Re-designed DH-220 with JFET Complementary Input Stage
- Linear Systems LSK489 and LSJ689
- Lateral MOSFET output stage
- Large class A region – good “First Watt”
- Very low distortion
- Very low noise – 104 dB A wtd re 2.83V