Development of a Low-Cost Programmable Microphone Preamp Gain Control IC for Pro Audio Applications

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THAT Corporation

Tonight's Presentation

- Introduction
- Professional Microphone Preamplifiers
- Digital Mic Preamp Gain Controllers
- Earlier Products
- Cost Reduction Measures
- Cost-Performance Tradeoffs
- Measured Performance
- Conclusions

Who's THAT?

- Founded in 1989
  - 2014 was our 25th anniversary!
- Spin-off from dbx Inc.
- Founders were dbx engineers
  - Paul Travaline, Gary Hebert, And Les Tyler
- Once made complete pro-audio products
- Now focused on Pro Audio ICs and Licensing

Professional Microphone Preamps

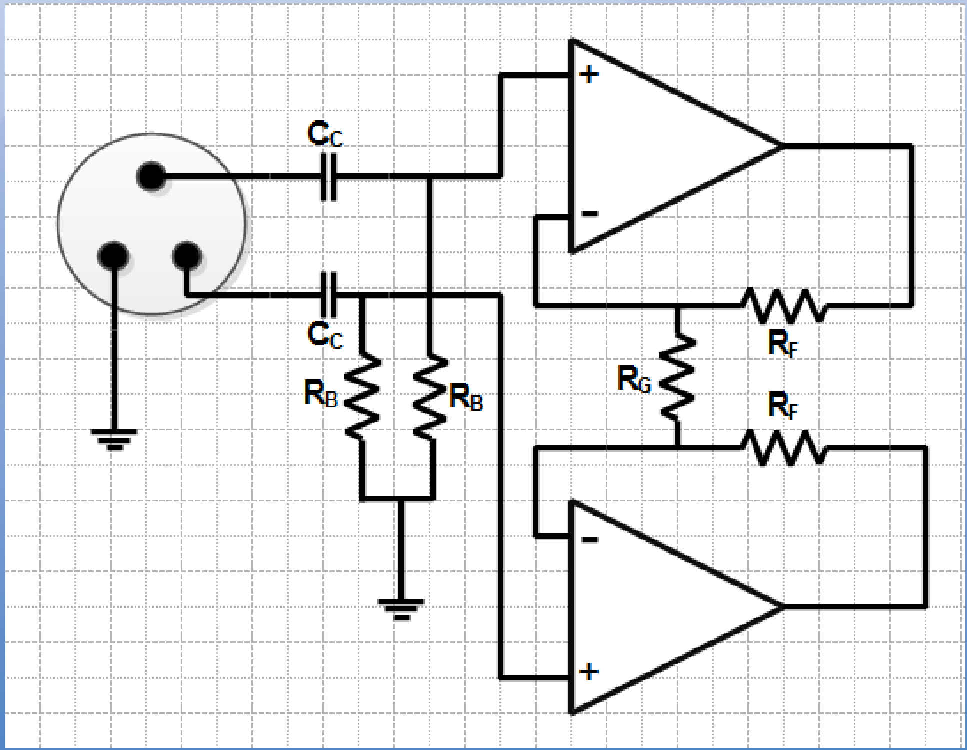
- Balanced (Differential) Input
- Low input noise required
  - On the order of 150Ω thermal noise
  - (-130.8 dBu in 20 Hz – 20 kHz BW)
- Wide gain range required
  - Mic sensitivities vary over at least 37 dB
  - Sound levels vary with application
- Max input level should be ≥ +16 dBu for the highest-output condenser microphones

Digital Control of Professional Microphone Preamps

- Many preamps are now front ends for A/D converters in digital audio products.
- Digital control of the gain gives a uniform user interface for these systems.
- It also allows enhanced automation features such as setup recall and automatic gain reduction in response to clipping.

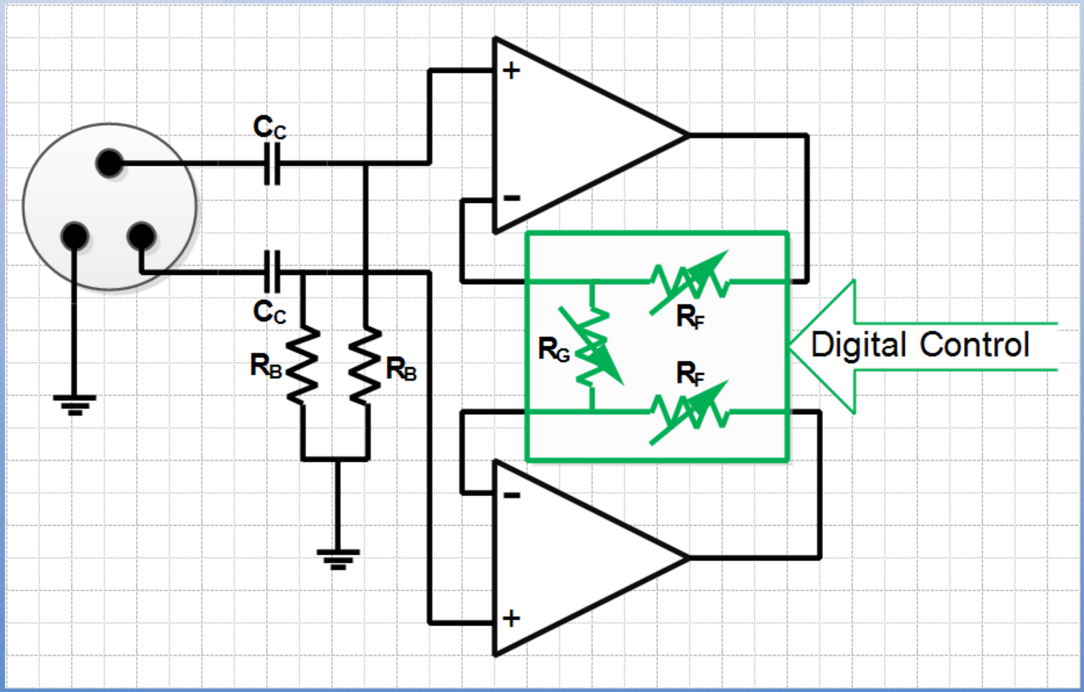
Typical Preamp Front End

- Differential gain $= 1 + (2R_F/R_G)$
- C_C capacitors block dc inputs and phantom power
- R_G low valued at high gains to minimize noise



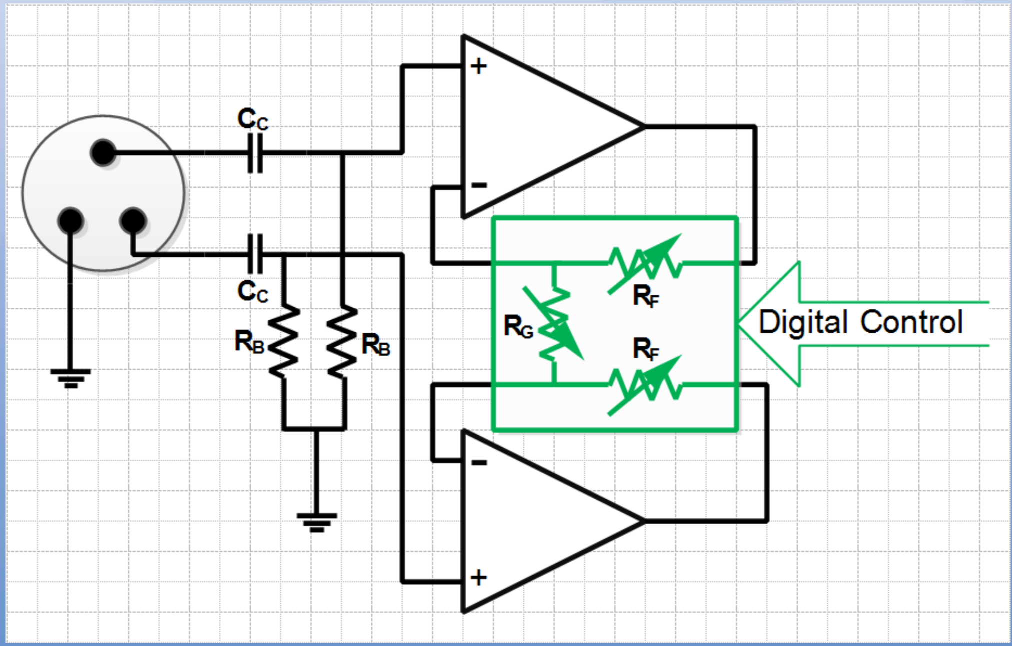
What's a Programmable Gain Controller?

- Digitally controlled feedback network for a low-noise differential amplifier



Programmable Gain Controller

- R_G gets small at high gains
- Small R_G implies low R_{ON} switches
- R_F/R_G is large at high gains

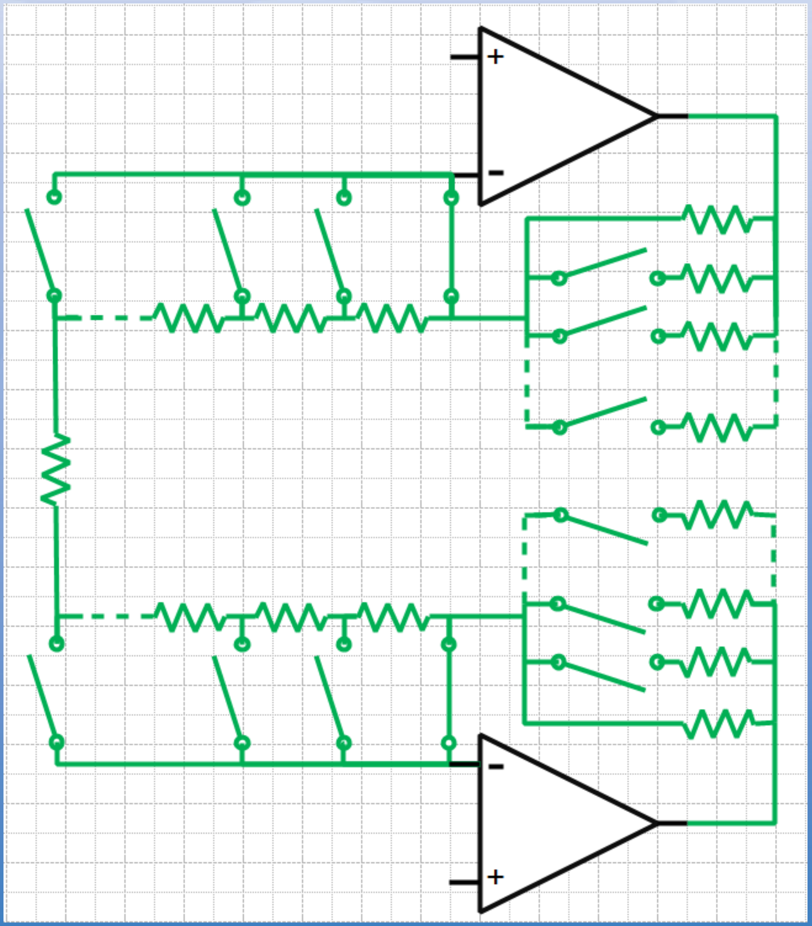


THAT's First Controllers

- 5171 - 1 dB/step
  - 13.6 dB – 68.6 dB
  - <.0008% THD, +24 dBu out, any gain
- 5173 - 3 dB/step
  - 0 dB – 60 dB
  - <.001% THD,+24 dBu out, any gain
- Accurate gains - +/-.5 dB max, +/-.15 dB typical
- DC servos

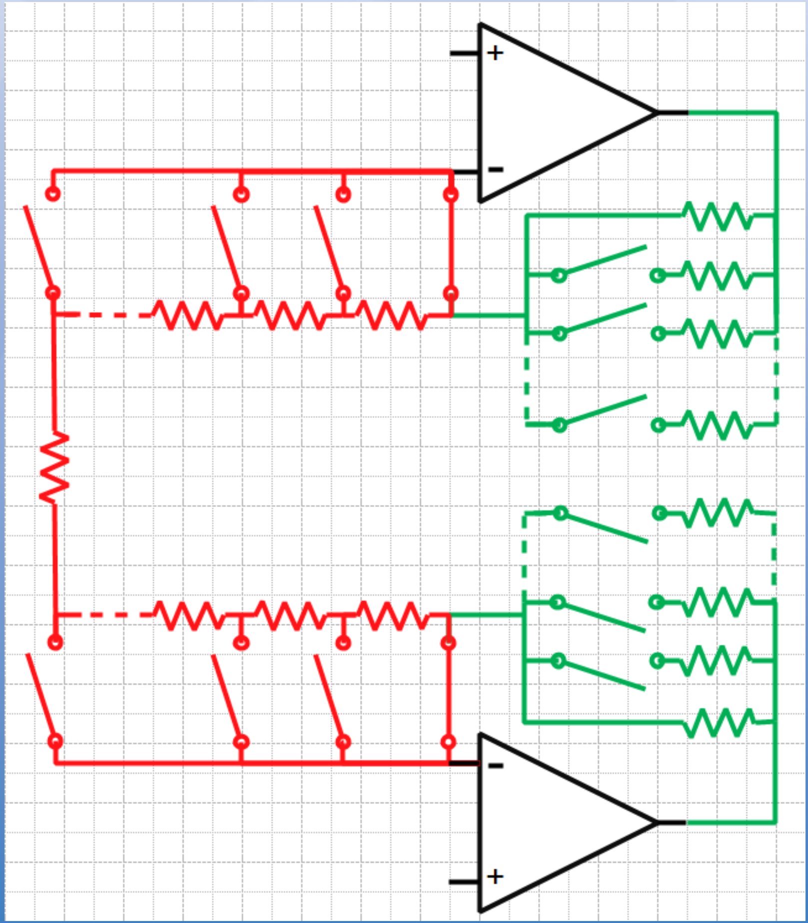
5171/5173 Topology

- Both R_F and R_G are varied using a combination of a tapped resistor string and a set of switched paralleling resistors.



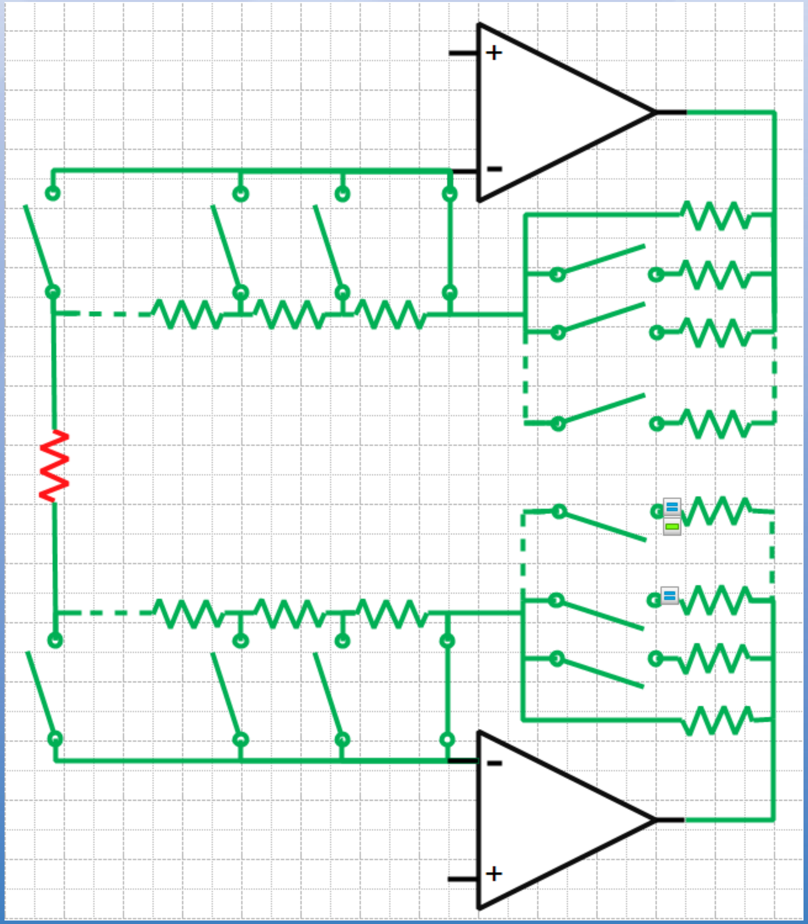
5171/5173 Topology

- Tapped resistor string is used for large steps
- Tapped string switches don't effect gain or THD, but do add noise



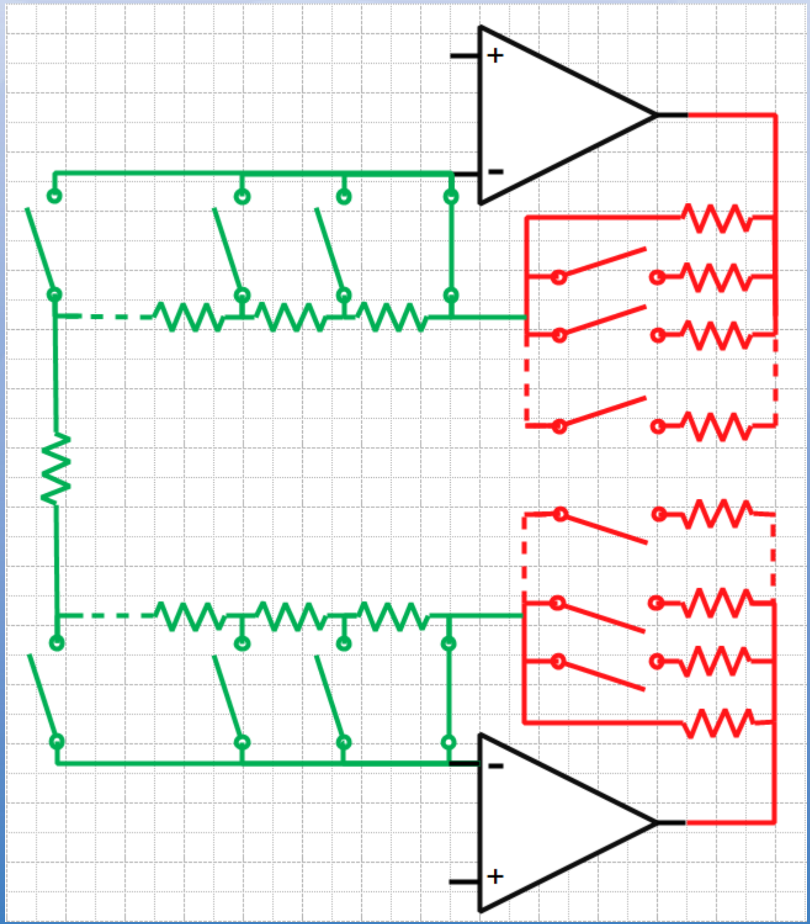
5171/5173 Topology

- Minimum RG (in red) is 5.6Ω in the 5171.
- This resistor is very wide and short.
- W/L≈109 for 610 Ω/sq. poly



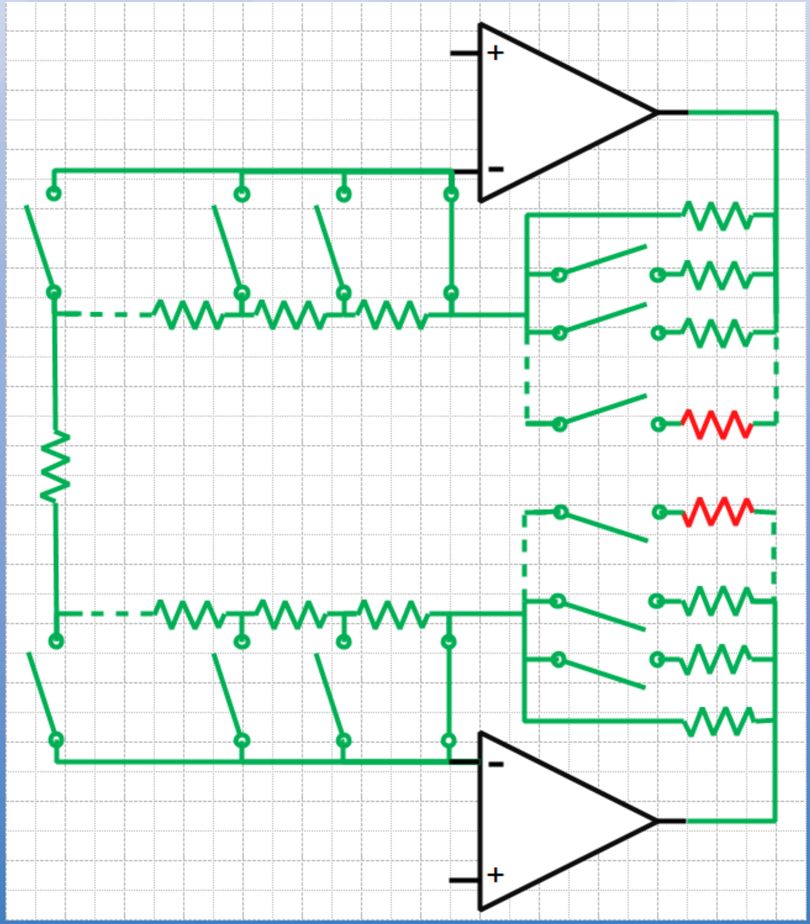
5171/5173 Topology

- Paralleling resistors are used for small steps
- Paralleling switches are in series with high-value resistors



5171/5173 Topology

- Maximum parallel R_F (in red) is 47 kΩ in the 5171.
- This resistor is narrow and long.
- W/L≈.013 for 610 Ω/sq. poly

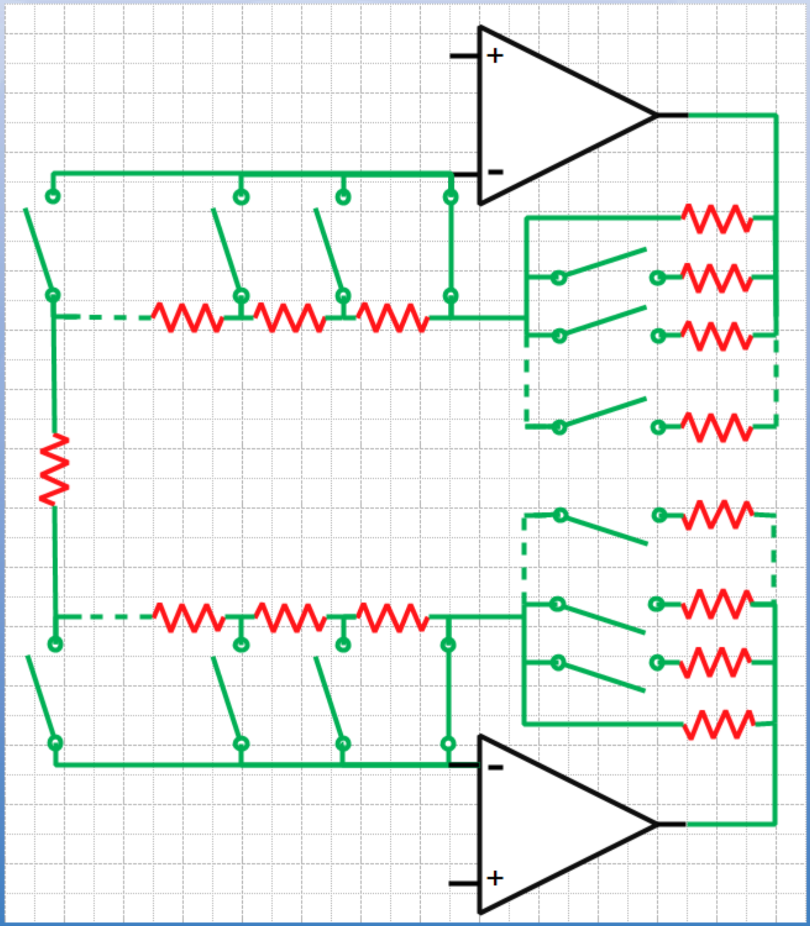


Show Me the Money

- The 5171 and 5173 have proven to be too expensive for many applications, particularly those at the entry level where some of the possible automation features might be most useful.
- So, what makes them expensive, and what do we trade off to make a less costly part?

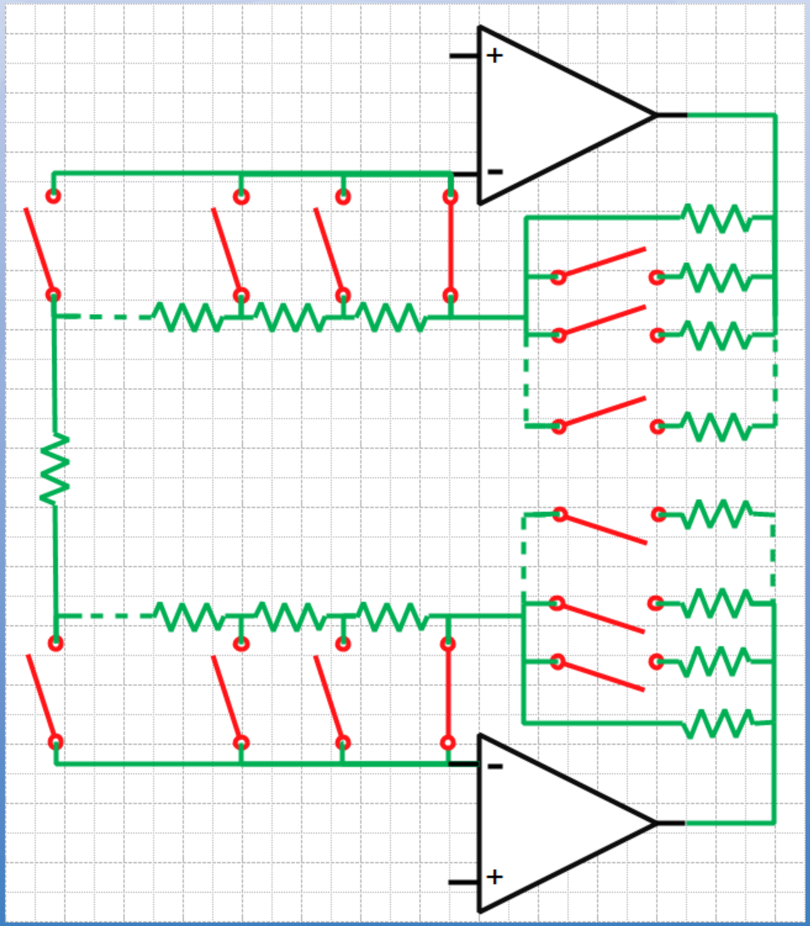
Resistors – Bigger is Better

- Ratio accuracy increases with resistor area.
- Distortion due to self heating is proportional to: $S_G * {I_{RMS}}^2 / W^{1.4}$



Switches – Bigger is Better

- R_{ON} is inversely proportional to device width
- Low R_{ON} minimizes noise from the tap-string switches
- High voltage capability also increases area

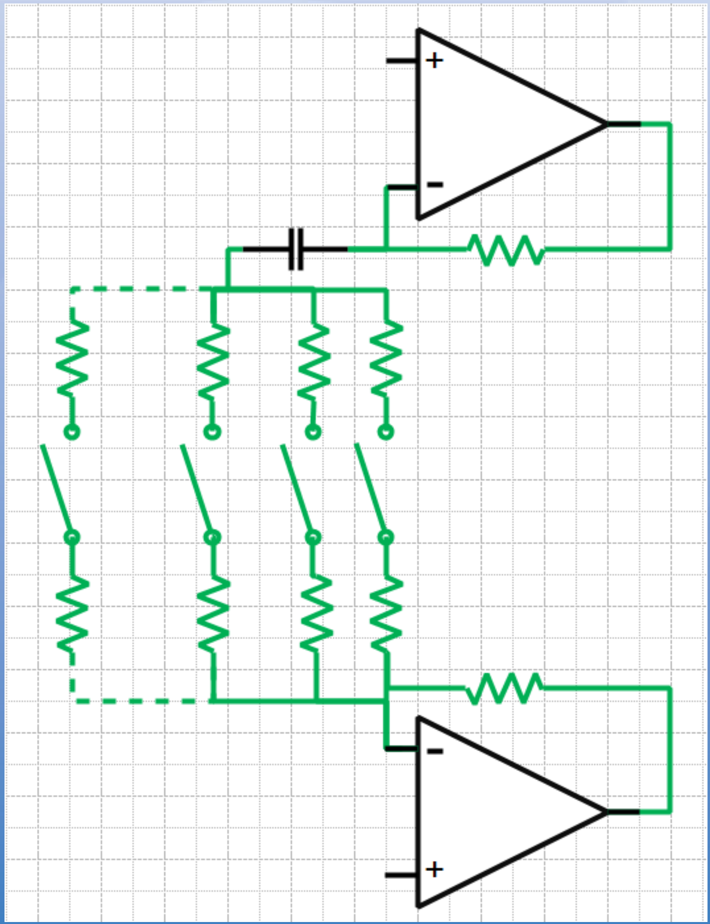


Cost Reduction – the Easy Stuff

- 3 dB per step
- Dual channel part
  - Saves some package cost
  - Small savings in SPI interface area
- Eliminate servo
  - Reduces die area
  - Reduces power
  - Requires large external capacitor

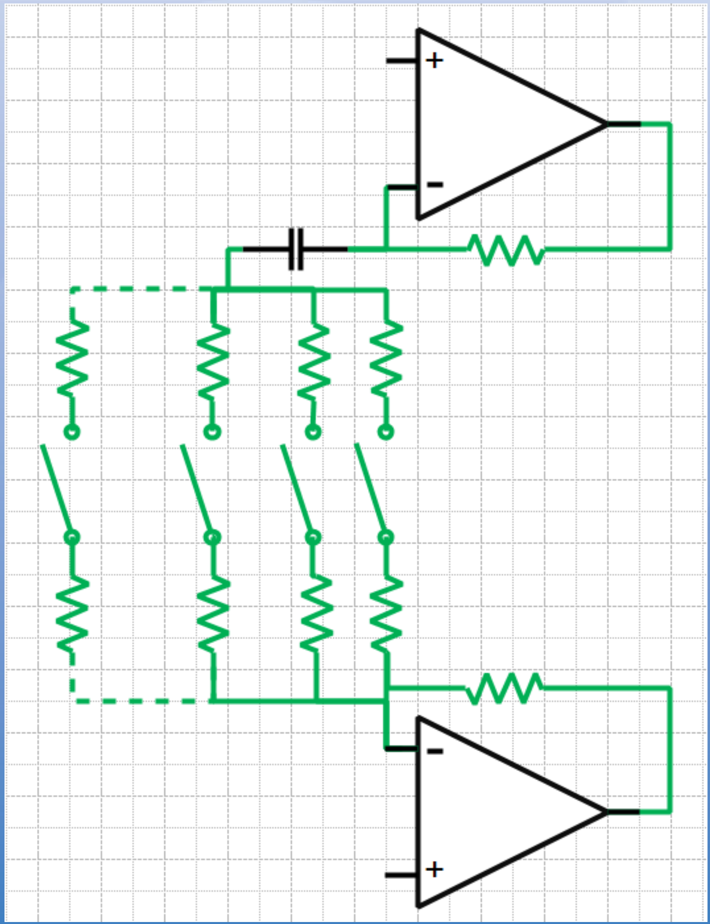
New Topology

- Variable R_G
- Fixed R_F
- Switch R_{ON} added to R_G
- ΔR_{ON} adds THD
- R_{ON} variation adds gain error

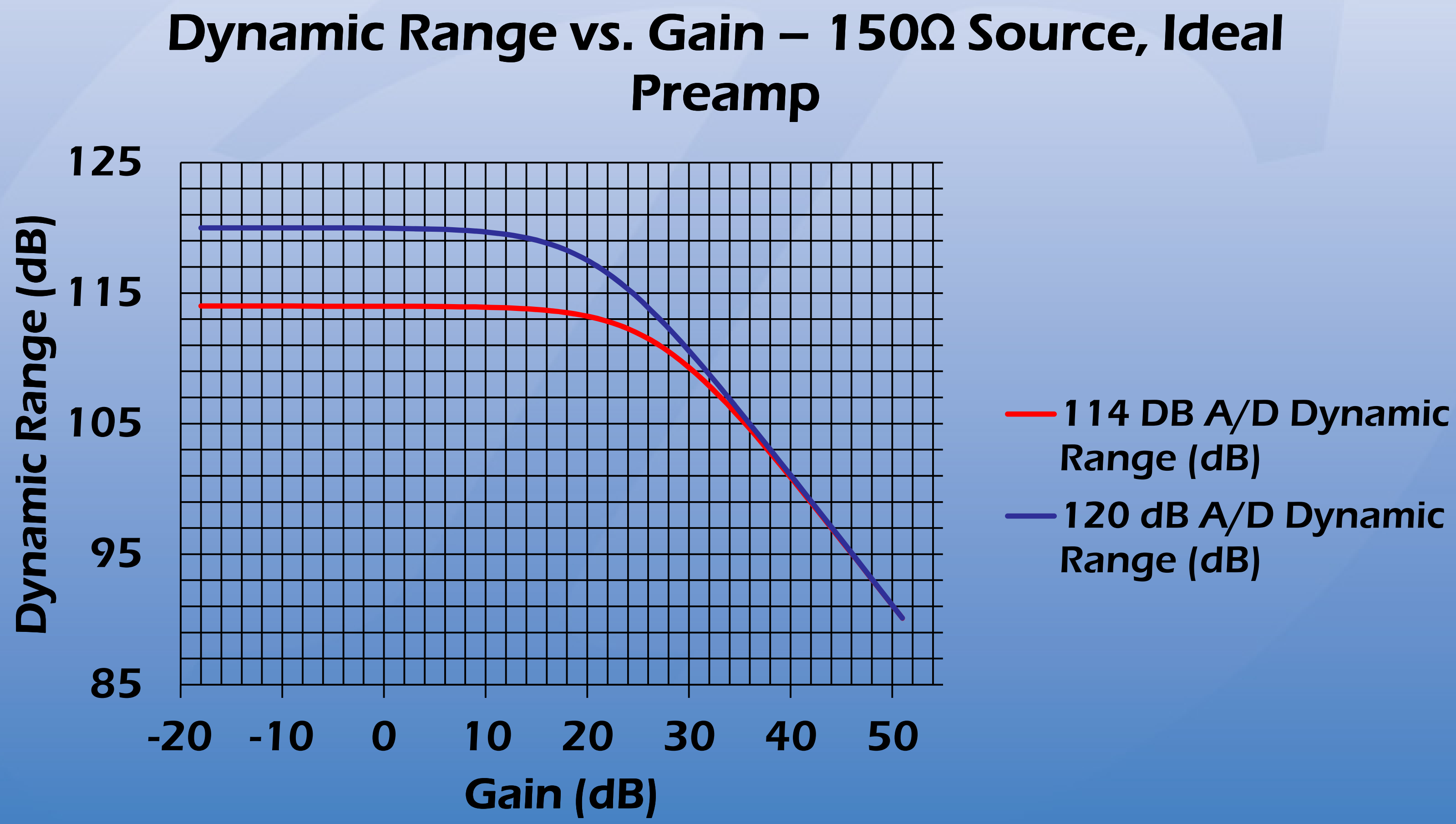


New Topology

- Dynamic gate drive minimizes THD due to ΔR_{ON}
- Reduced max gain (51 dB) saves die area

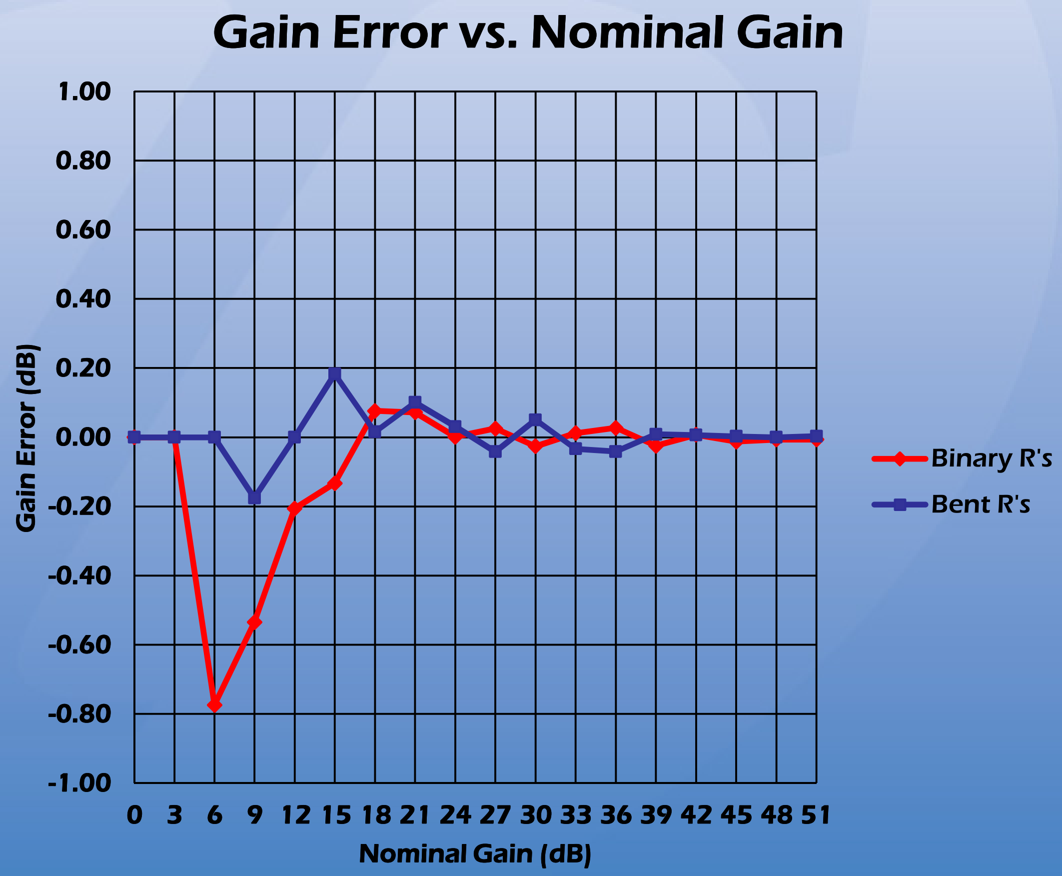


How Much Gain?



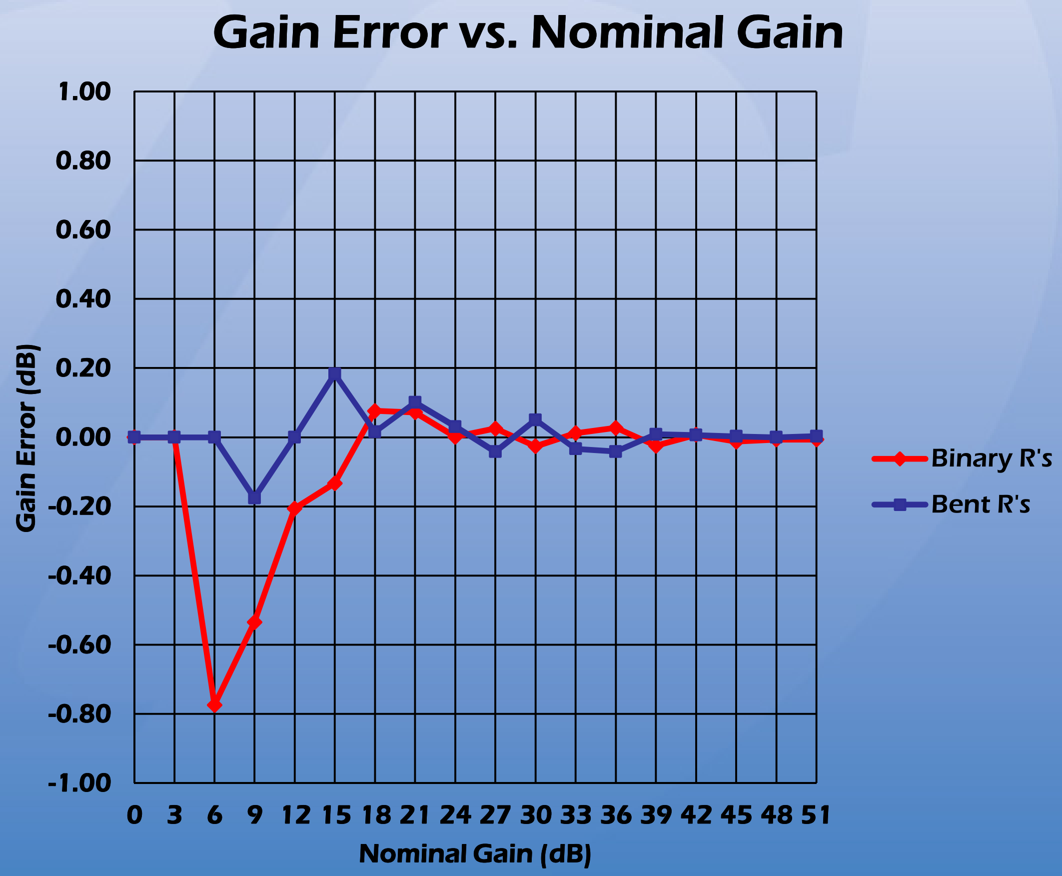
"Bent Binary" R_G Scheme

- Binary resistances for R_G leads to gain error at low gains
- Bending a few of the LSBs gives a good fit (+/-.2 dB nominal error)



"Bent Binary" R_G Scheme

- 0 – 51 dB gain range with 10 switches
- Actual gain accuracy will vary since R_{ON} doesn't track poly resistors



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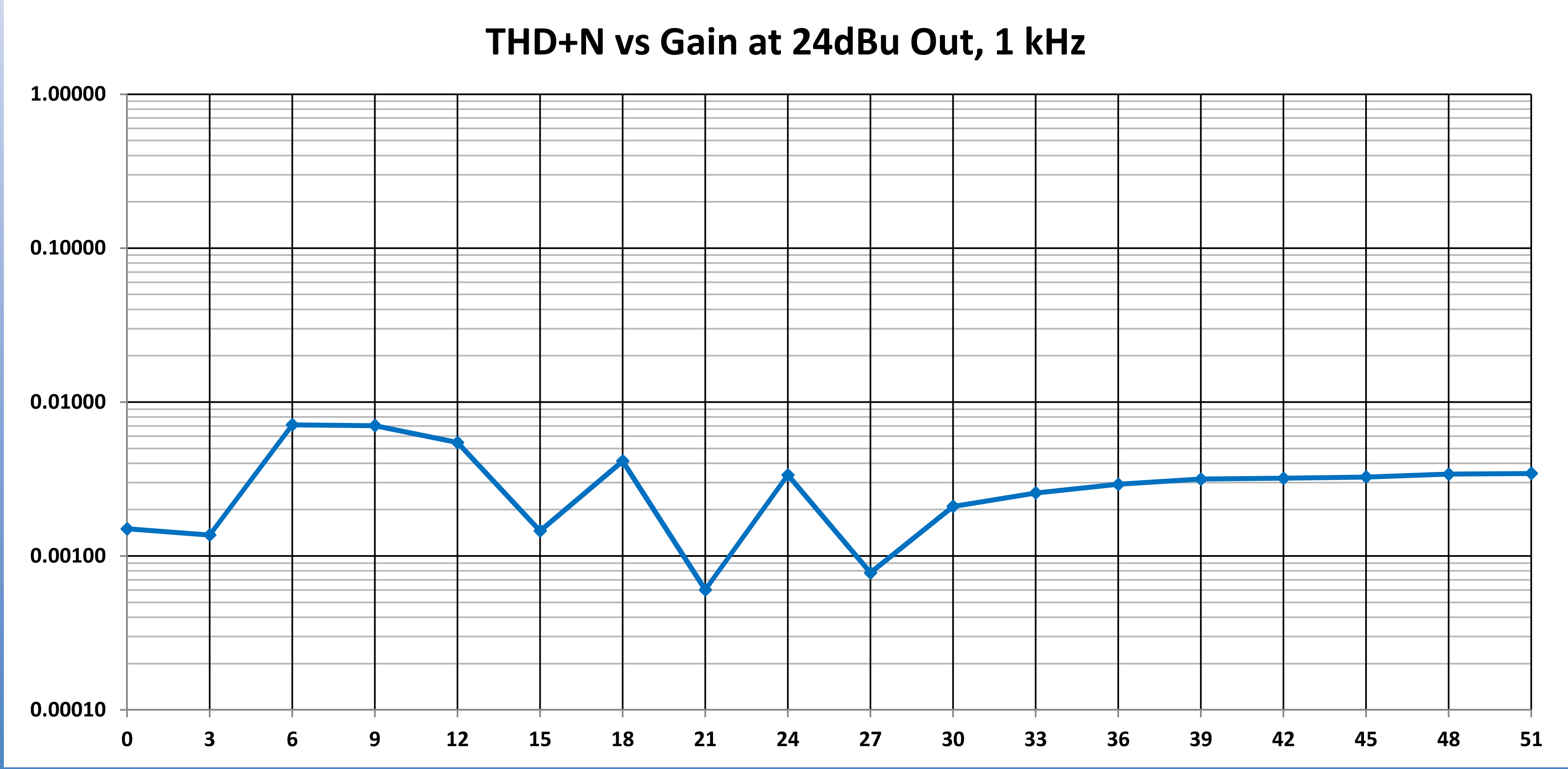
Resistor Area Reduction

- Resistors scaled down to meet the target die area
- These become the dominant distortion mechanism
- THD due to resistor self heating is almost pure 3rd harmonic

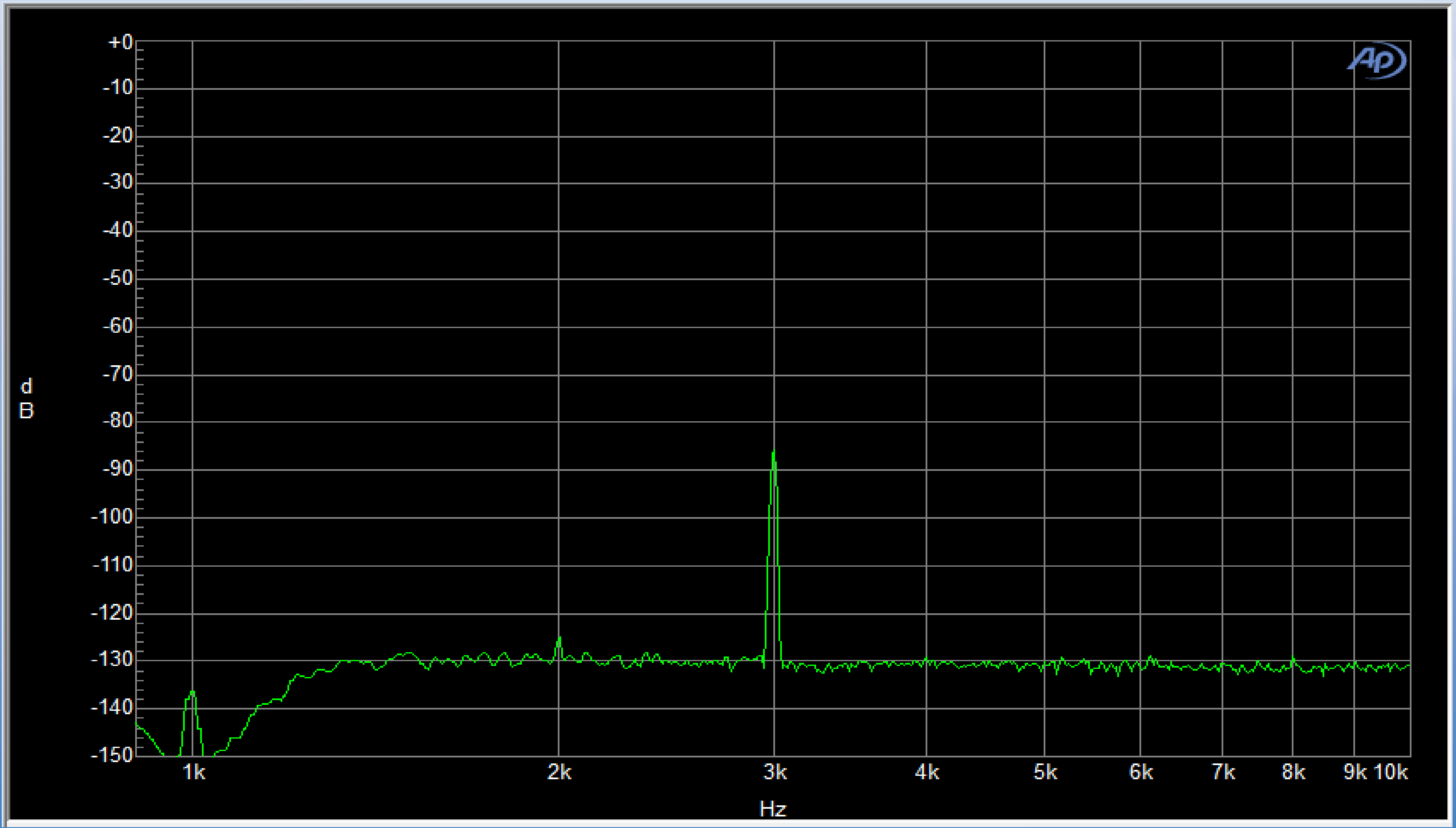
Performance

- EIN with THAT 1580 = -128.3 dBu with 150Ω R_S, 20 Hz – 20 kHz BW, 51 dB gain
- Gain Accuracy
  - +/-.5 dB 0 - 39 dB
  - +/-1 dB 42 – 51 dB

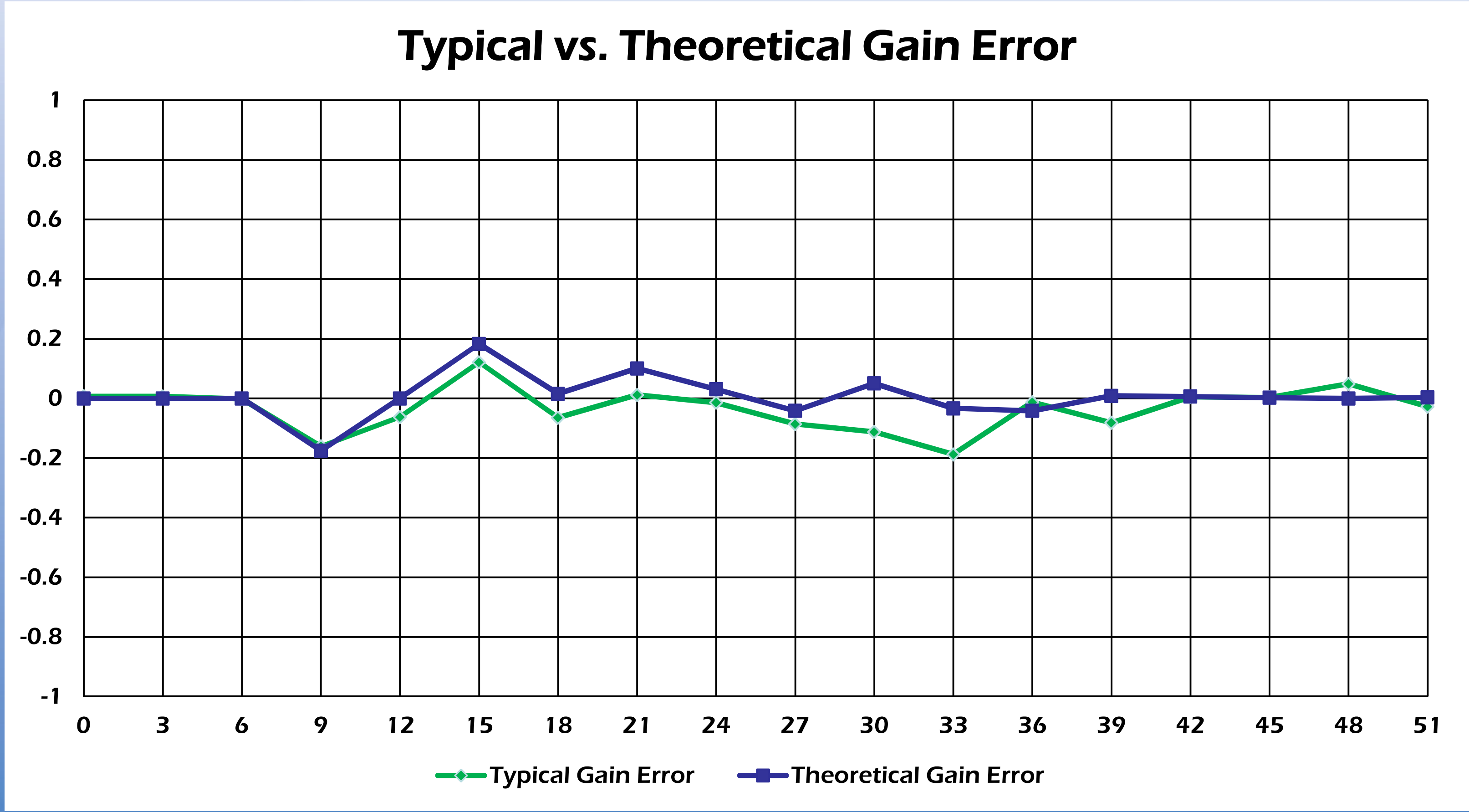
Performance



Performance



Performance



Additional Features

- Zero-crossing detectors (ZCDs) for each channel
- Internal time-out clock counter for ZCD
- 1 general purpose logic output (GPO) per channel
- GPOs can be sync'd to the ZCD
- Independent connections for R_F resistors for discrete preamp designs that require this

Conclusions

- We achieved a 55% cost reduction per channel compared to our 5173
- THD performance was compromised in a manner that seems acceptable to most
- Noise performance is actually slightly better than the previous designs at most gains

Acknowledgements

Thanks to Fred Floru of THAT Corporation for his help in reviewing this presentation.

Thanks to Rene Jaeger for inviting me to speak tonight.

Questions?