THAT Corporation

Department Engineering

Subject **THAT New Digitally Controlled Mic Preamp**

Name THAT Corporation

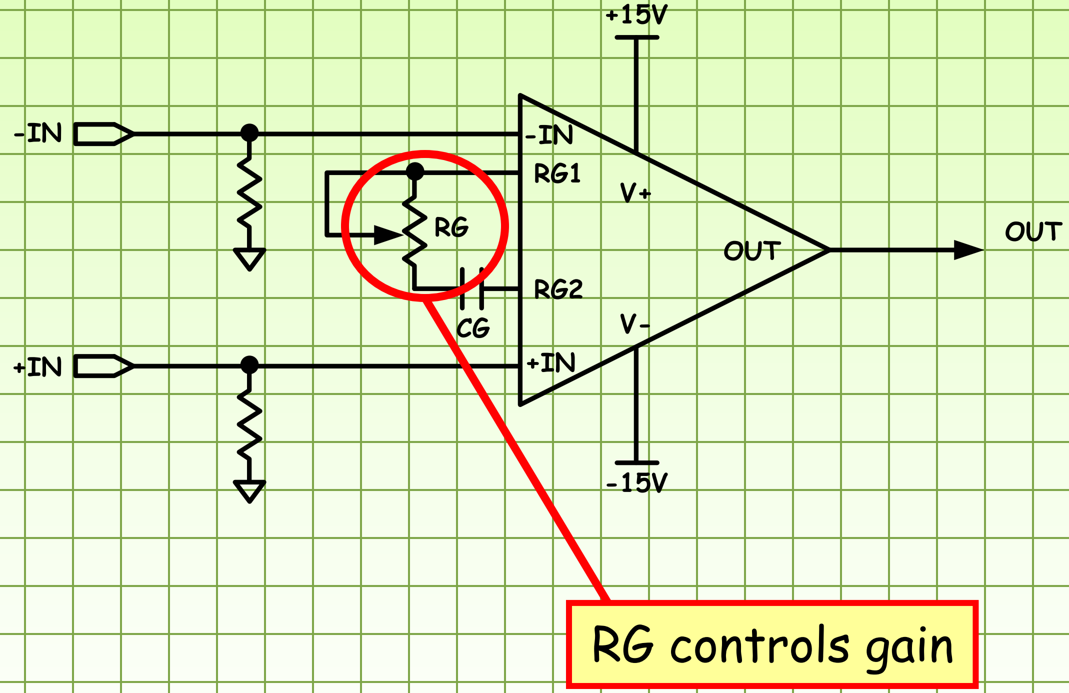
Address 127th AES Convention
New York, Oct 2009

Seminar Outline

- Conventional mic preamp solutions
- What customers asked for
- THAT1570/5171 chipset
- 1570/5171 Demo Board
- How we met customer demands

Conventional Analog Mic Preamp

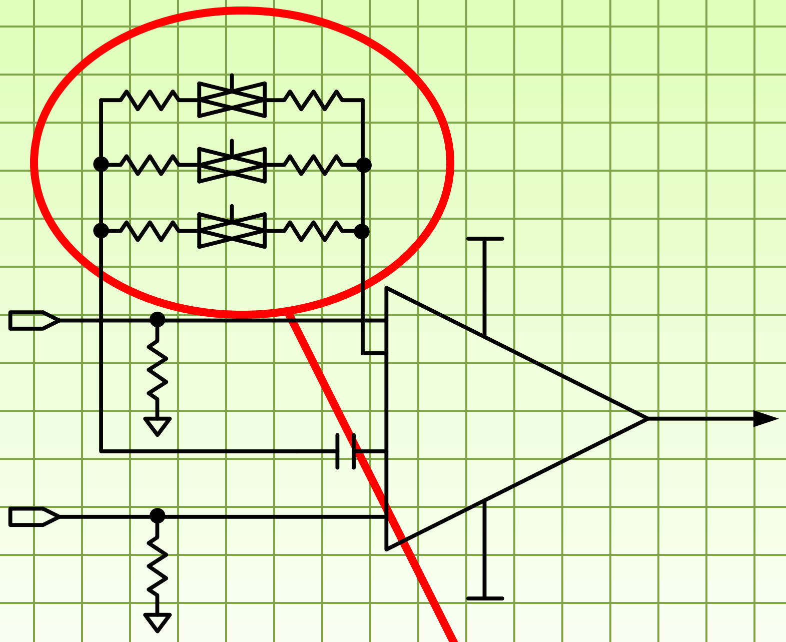
Mic Preamp, ala THAT1512



RG is usually a pot

Conventional Digitally Controlled Mic Preamp

- Use a switched resistor ladder for RG

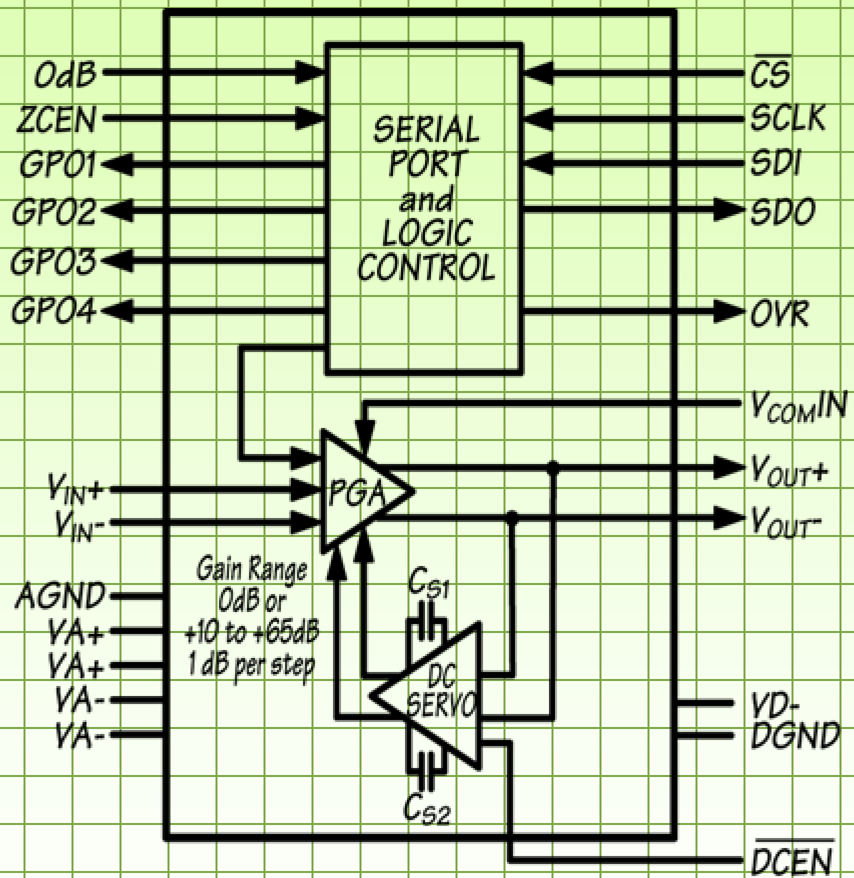


Problems:

- Expensive
- Lots of PCB real estate
- Ron problems
- Complex control logic

Relays or analog switches (shown) and resistor ladder replace RG pot

Conventional Solutions - PGA2500



CS1 and CS2 are external DC servo integrator capacitors, and are connected across CS11/CS12 and CS21/CS22 pins, respectively.

Cool, but:

- Expensive
- Low Headroom
- Requires Input Pad
- Switching glitches

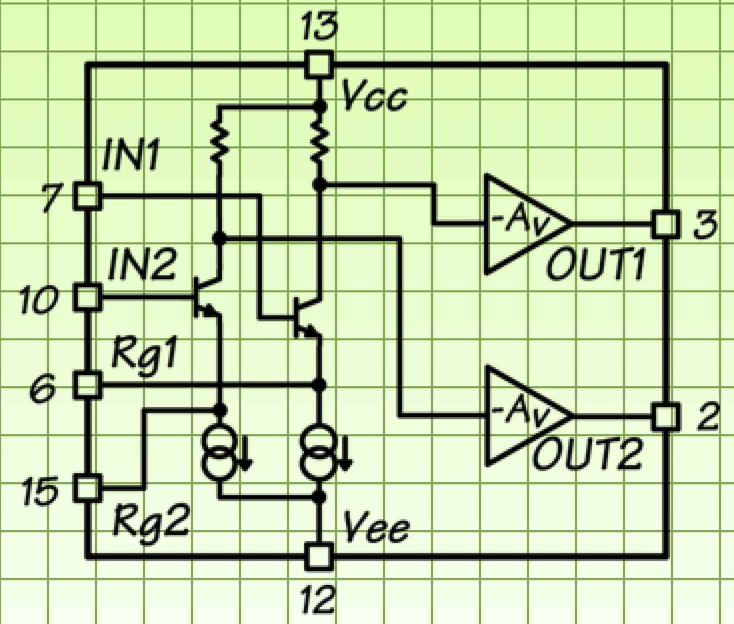
What Customers Asked Us For

- Digital Gain Control with:
  - More headroom (no input pad)
  - No switching glitches
  - Lower cost

THAT DigMicPre Solution

THAT1570

- Low Noise:
  - 1 nV/√Hz EIN (60 dB gain)
  - 18.5nV/√Hz EIN (0 dB gain)
- Low THD+N:
  0.0003% <30 dB gain
  0.0008% @ 40 dB gain
- Low Current: 7.5 mA typ
- Wide BW: 4.2MHz @40dB gain
- High Slew Rate: 53 V/µs
- Wide Signal Swing: >28.7dBu (±18V supplies)
- Gain adjustable from 0 to 70dB
- Differential output
- Small 4 x 4mm QFN16 package



1570 Claim to Fame

- External RF (RA and RB) allows impedances to be optimized
- Lowest noise monolithic audio preamp available today
- Extremely high dynamic range:
  - 127dB (0dB gain, ±18V supplies)
  - 103dB (60dB gain, ±18V supplies)
- Tiny 4x4mm QFN16 package

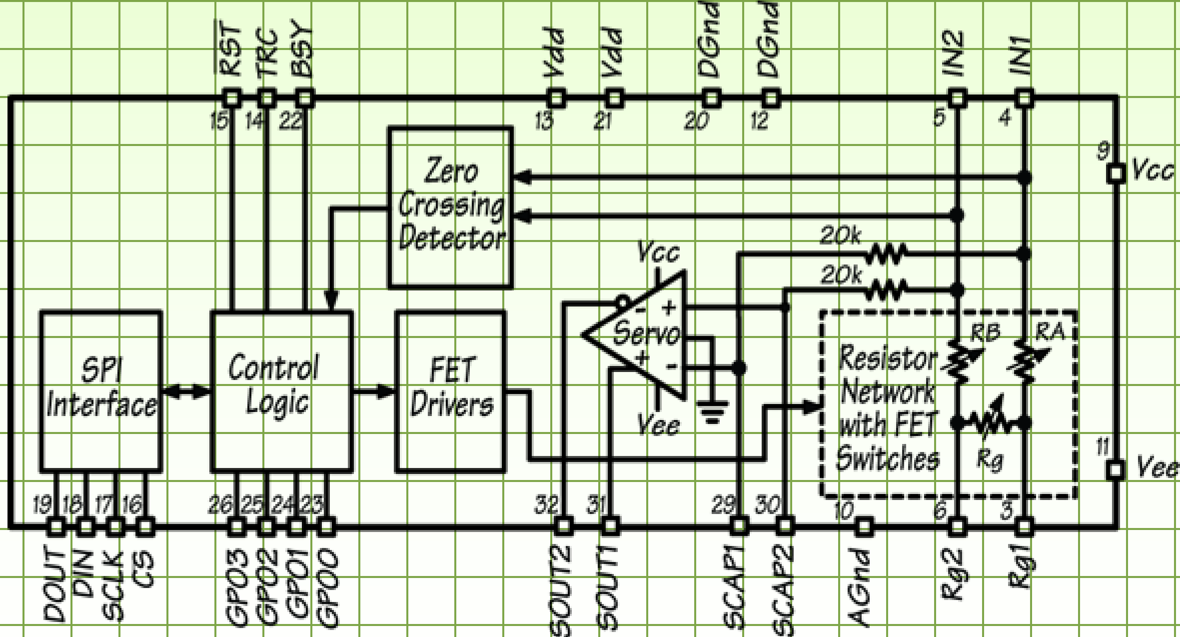
Why Didn't We Use Our 1510 or 1512?

- Both have feedback resistors (RA and RB) built into the chip
- We wanted to vary RA and RB to optimize noise at low gains
- External RA and RB also enable a more optimal interface to the digital gain controller…

THAT 5171 – High-Performance Digital Preamplifier Controller IC

The five major components of the 5171 are:

- Resistor Network & FET Drivers
- Control Logic
- SPI Interface
- Servo Amplifier
- Zero Crossing Detector



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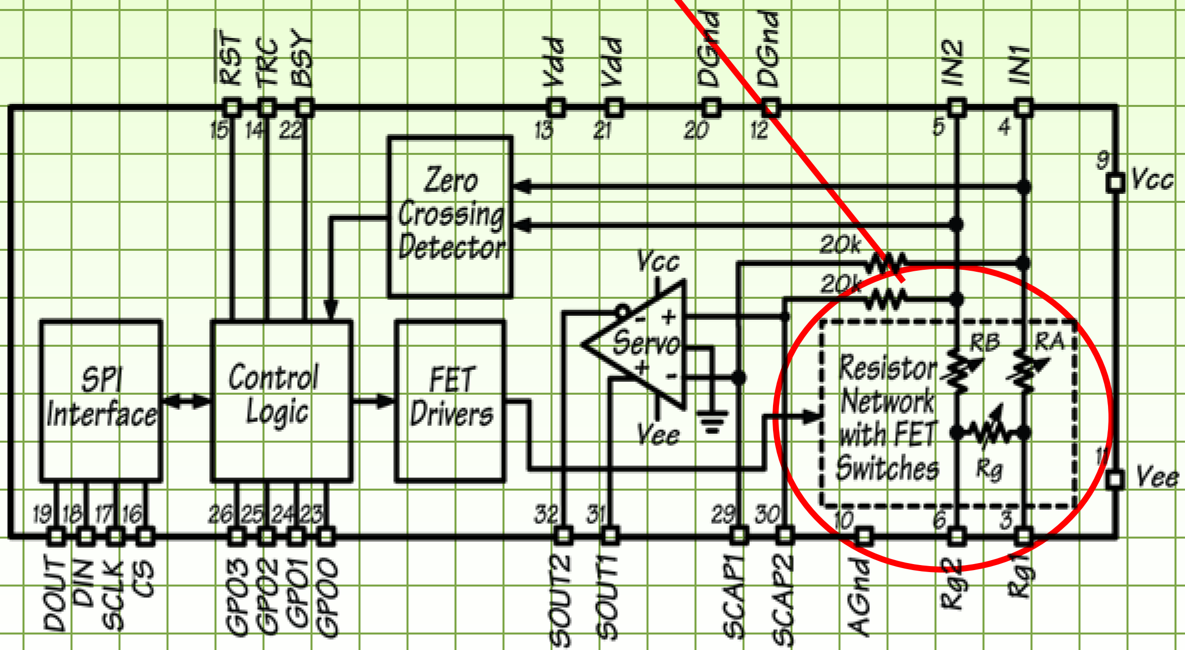
5171 Features

Digitally programmable gain controller for any current feedback amplifier (1570 or a discrete front end)

Integrated RG, RA, and RB precision resistor network with CMOS FET switching, optimized for low source impedance applications



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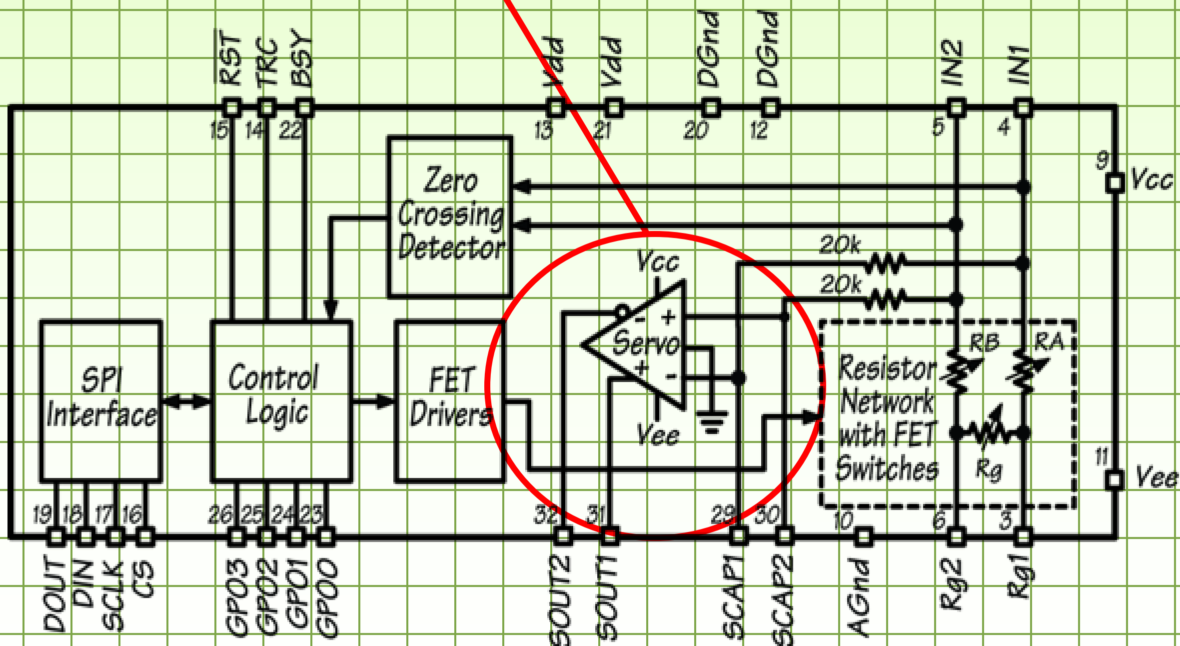
5171 Features

Digitally programmable gain controller for any current feedback amplifier (1570 or a discrete front end)

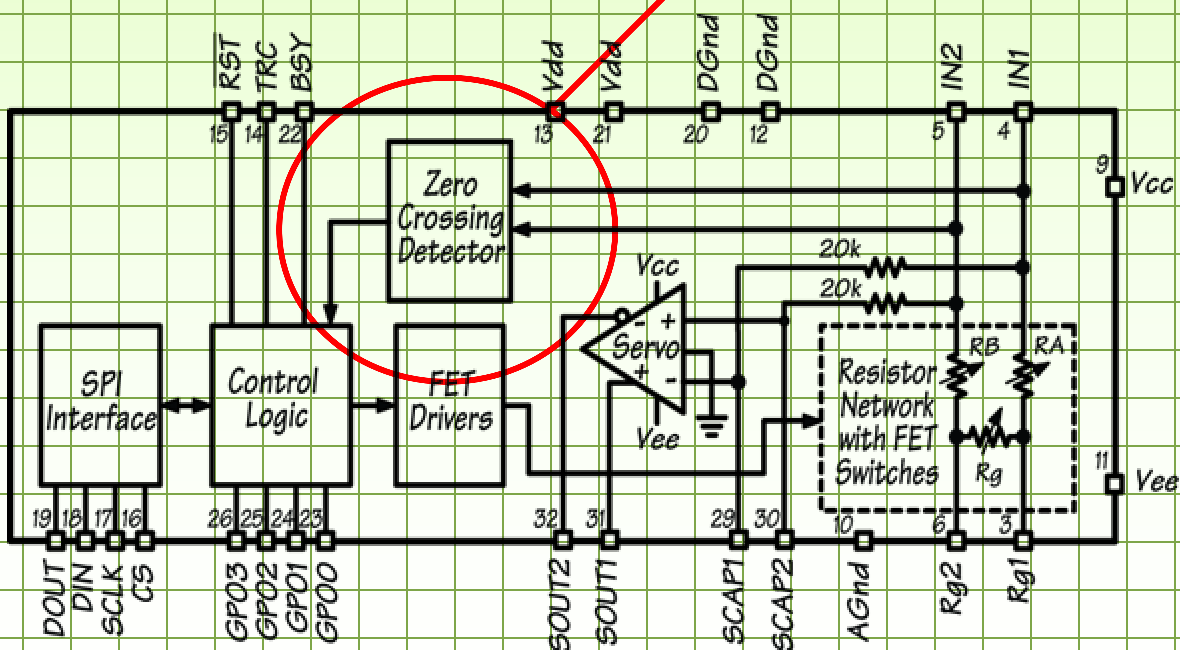
Integrated differential servo



5171 Features

Digitally programmable gain controller for any current feedback amplifier (1570 or a discrete front end)

On board zero-crossing detector w/ adjustable time-out



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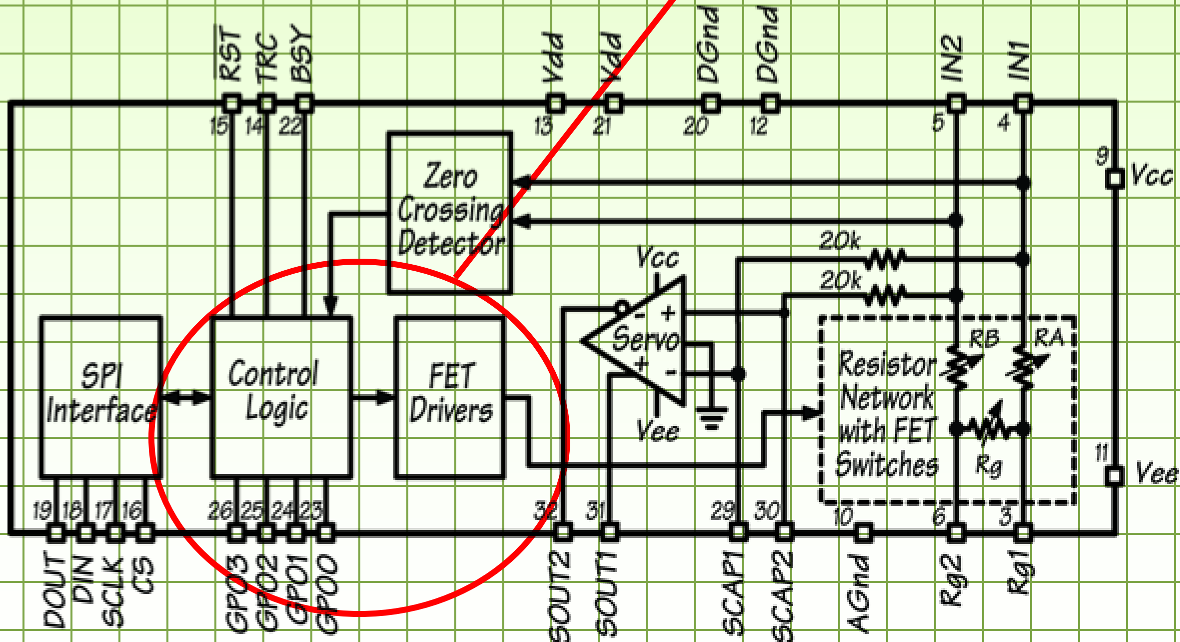
5171 Features

Digitally programmable gain controller for any current feedback amplifier (1570 or a discrete front end)

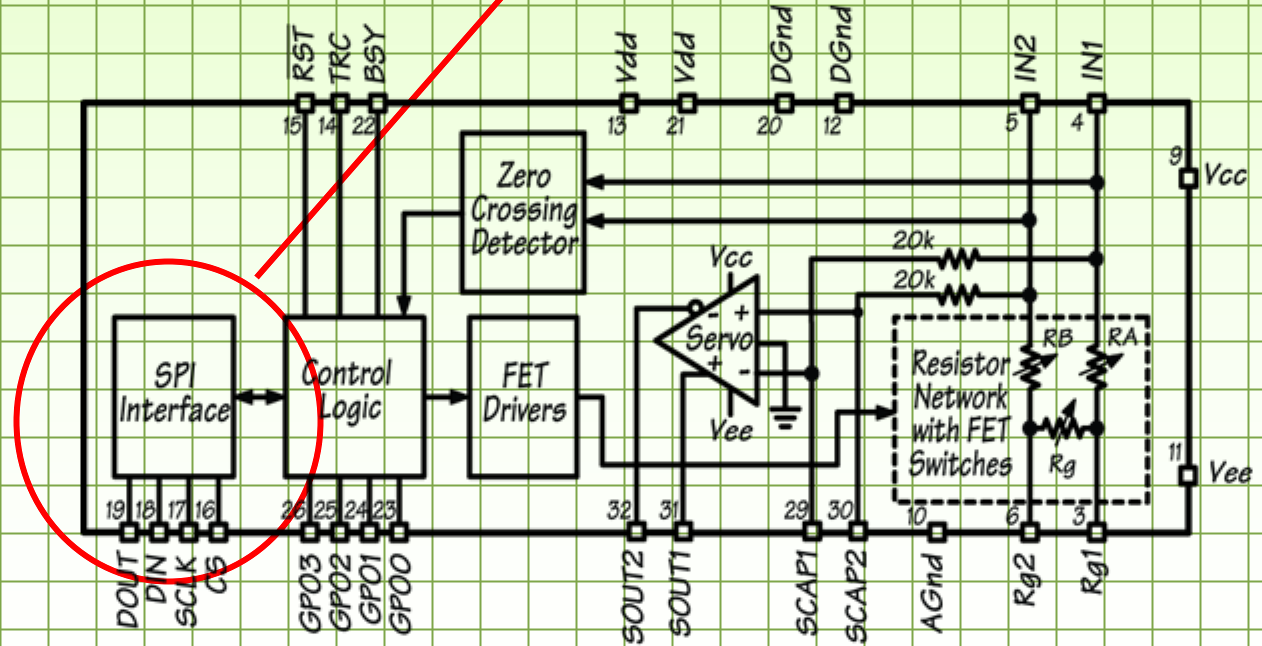
- Patent-pending zipper noise reduction techniques
- Four general-purpose digital outputs



5171 Features

Digitally programmable gain controller for any current feedback amplifier (1570 or a discrete front end)

Flexible, addressable SPI control interface



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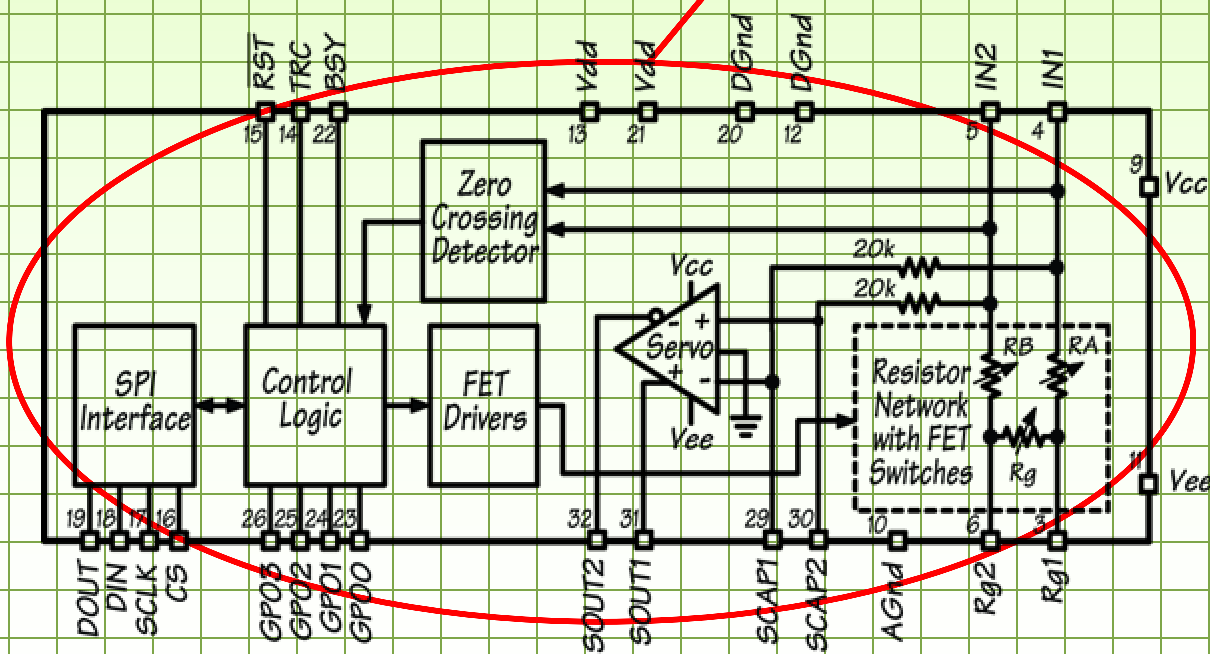
5171 Features

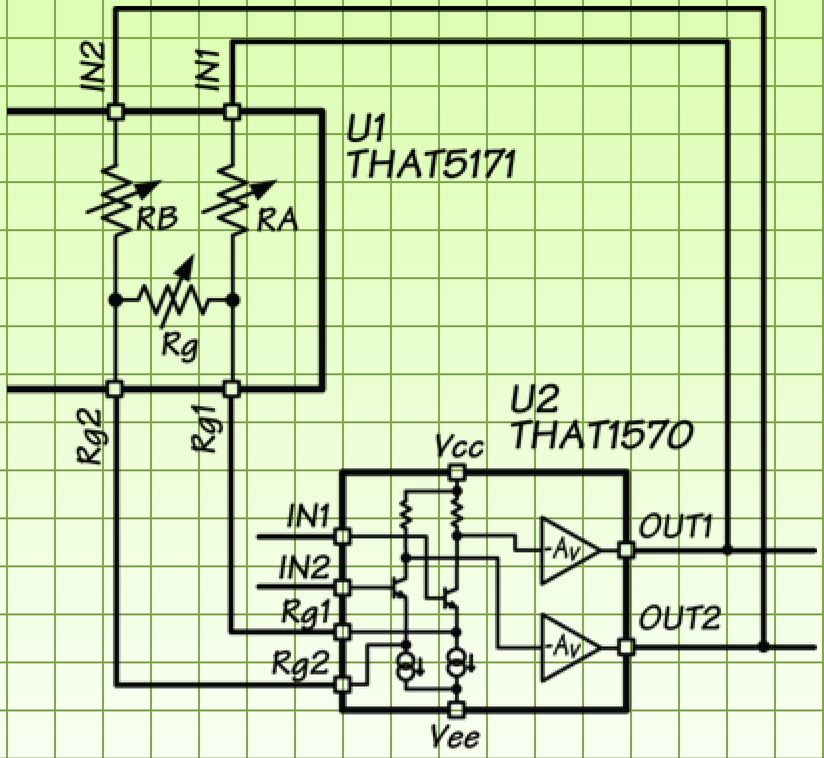
Digitally programmable gain controller for any current feedback amplifier (1570 or a discrete front end)

Small 7x7mm QFN32 package



5171 Resistor Network

- The Resistor Network is basically a U-pad formed by three resistors – Rg, RA and RB
- Ability to vary RA and RB as well as RG allows impedance optimization
- We can vary RAs and RBs and achieve more steps with fewer resistors
- Network can be turned around to yield a digitally controlled analog attenuator, but we'll leave that to you as an exercise



5171 SPI Interface

- Addressable
  - GPO pins set 3-bit address during reset
  - Up to eight devices can share one chip select
- Supports read-back
  - Very handy during development
  - Enables dynamically configurable "plug and play" architectures
  - Enables fault tolerant code
- Provides the PCB layout simplicity of daisy-chaining with the speed and flexibility of an addressable memory architecture

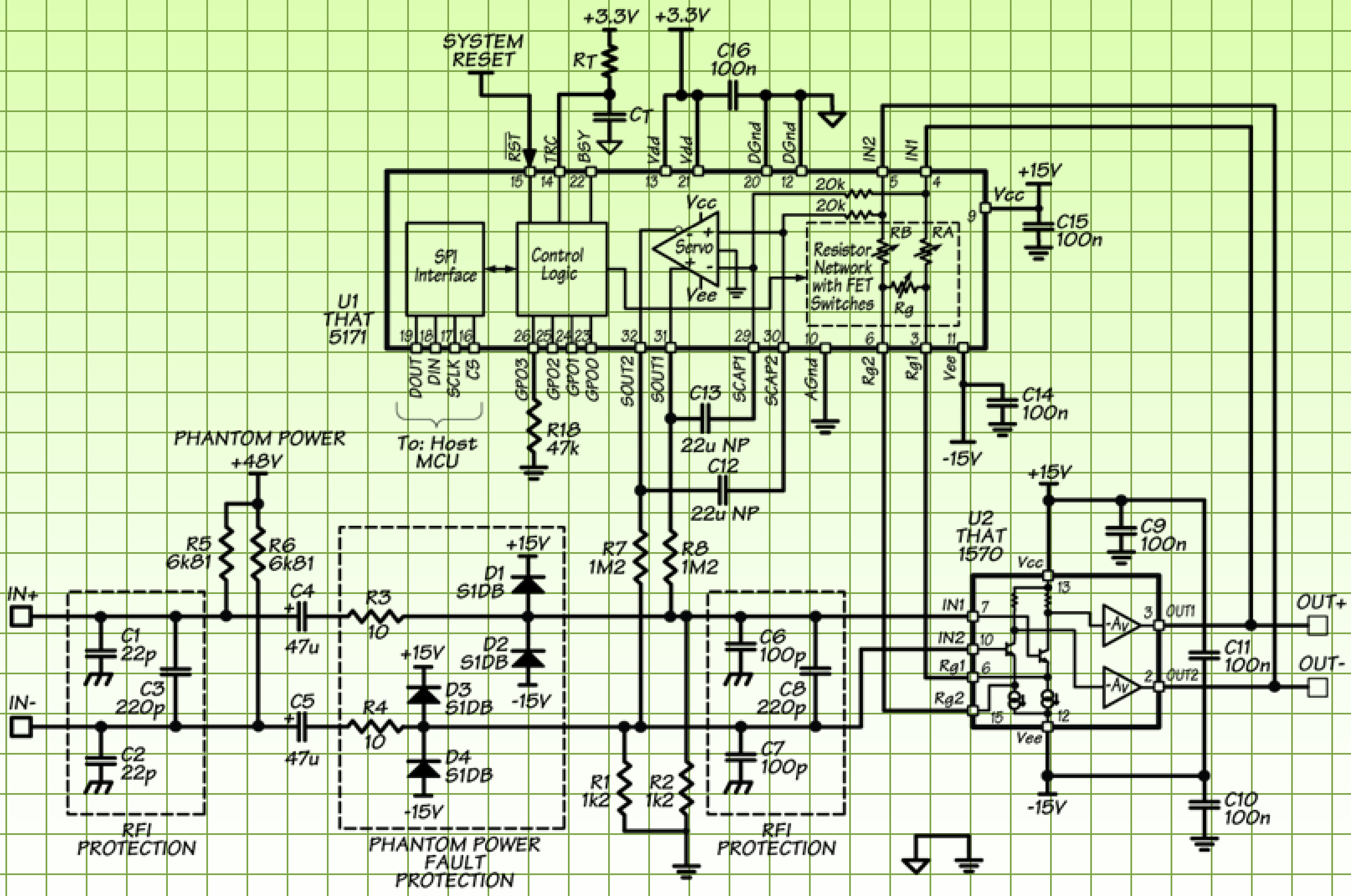
5171 Servo Amplifier

- Minimizes differential DC offset at preamp output
- Servo is an integrator around the gain stage (e.g. 1570)
- As the loop settles, the gain stage's output is driven to the input offset voltage of the servo (1.5mV max.)
- See 5171 datasheet for analysis of loop timing vs audio BW

5171 Zero Crossing Detector

- Constrains gain changes to zero crossings (when audio signal is < 5mV)
- Time-out forces a gain change if no zero crossing occurs
  - Time-out is adjustable with external RC
- BSY pin (and software readable flag) indicates when device is waiting for a ZC
  - Use to sync external processing to gain updates
- Defeatable ("Immediate" gain update mode)

1570 + 5171


+3.3V
+3.3V
SYSTEM RESET
RT
C16 100n
CT
U1 THAT 5171
SPI Interface
Control Logic
Servo
Vcc
Vee
Resistor Network with FET Switches
RB
RA
Rg
20k
20k
+15V
C15 100n
C14 100n
-15V
To: Host MCU
R18 47k
C13 22u NP
C12 22u NP
PHANTOM POWER +48V
R5 6k81
R6 6k81
IN+
IN-
C1 22p
C2 22p
C3 220p
C4 47u
C5 47u
R3 10
R4 10
D1 S1DB
D2 S1DB
D3 S1DB
D4 S1DB
R7 1M2
R8 1M2
R1 1k2
R2 1k2
C6 100p
C7 100p
C8 220p
U2 THAT 1570
C9 100n
C10 100n
C11 100n
OUT+
OUT-
RFI PROTECTION
PHANTOM POWER FAULT PROTECTION
RFI PROTECTION

1570 + 5171 Specifications

- Gain range
  - +5.6dB, and +13.6 to +68.6dB in 1dB steps
  - Or, 0dB and 8~63dB in 1dB steps, with -5.6dB attenuator
- Gain accuracy:
  - 0.15dB max error at each gain step
- Wide input swing:
  - +21dBu with ±15V supplies (+5.6dB gain)
- Wide output swing:
  - +26dBu on ±15V supplies
- Wide power supply range:
  - +/-5V to +/-17V
- EIN
  - 1.5 nV/√Hz (68.6 dB gain)
  - 22 nV/√Hz (0 dB gain)
- Dynamic Range:
  - 120dB @ 30dB gain (1kHz; Vout = +21dBu; 22kHz BW)
- THD+N:
  - 0.0003% @ 30dB gain (1kHz; Vout = +21dBu; 22kHz BW)

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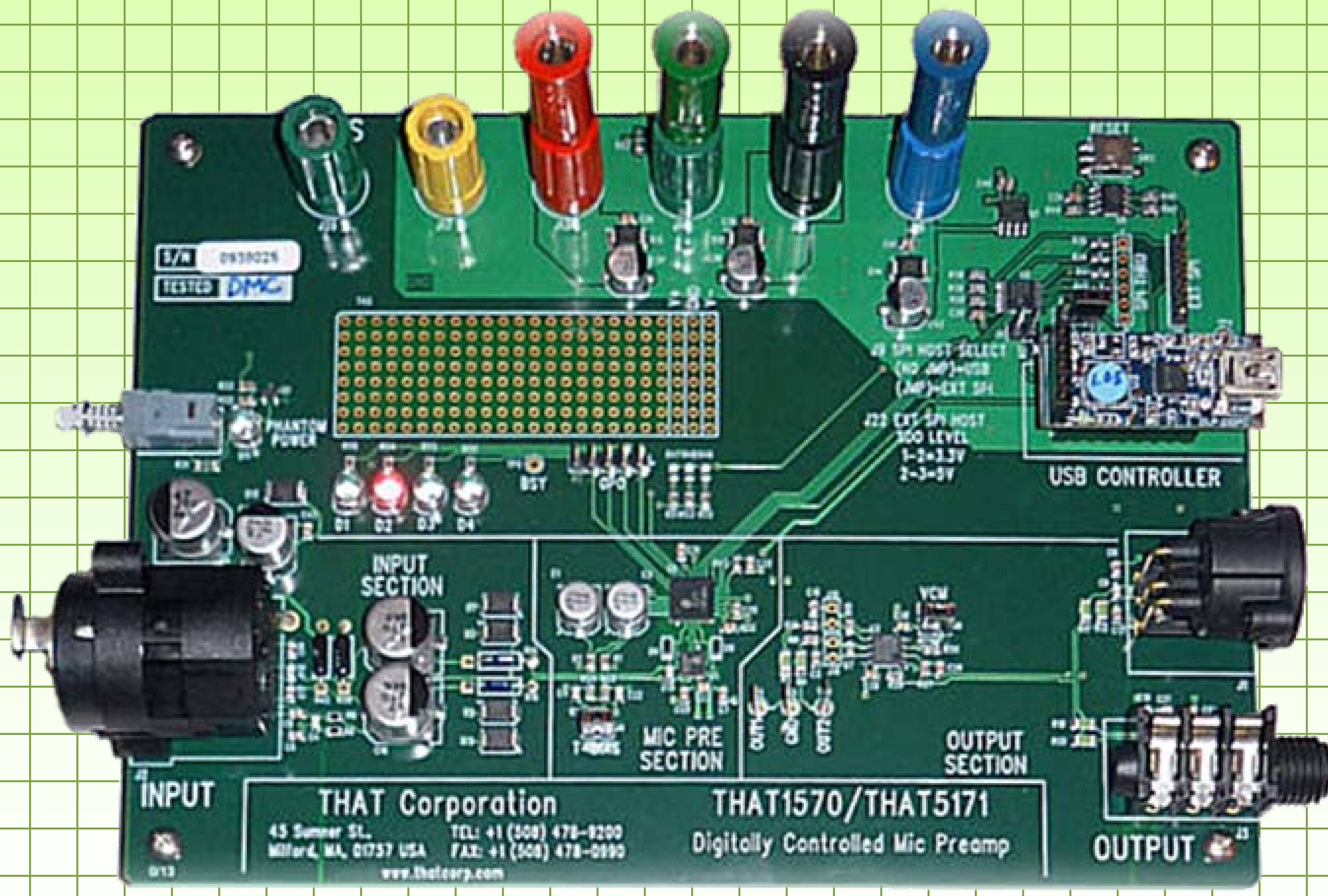
Why the Funny Gain Numbers?

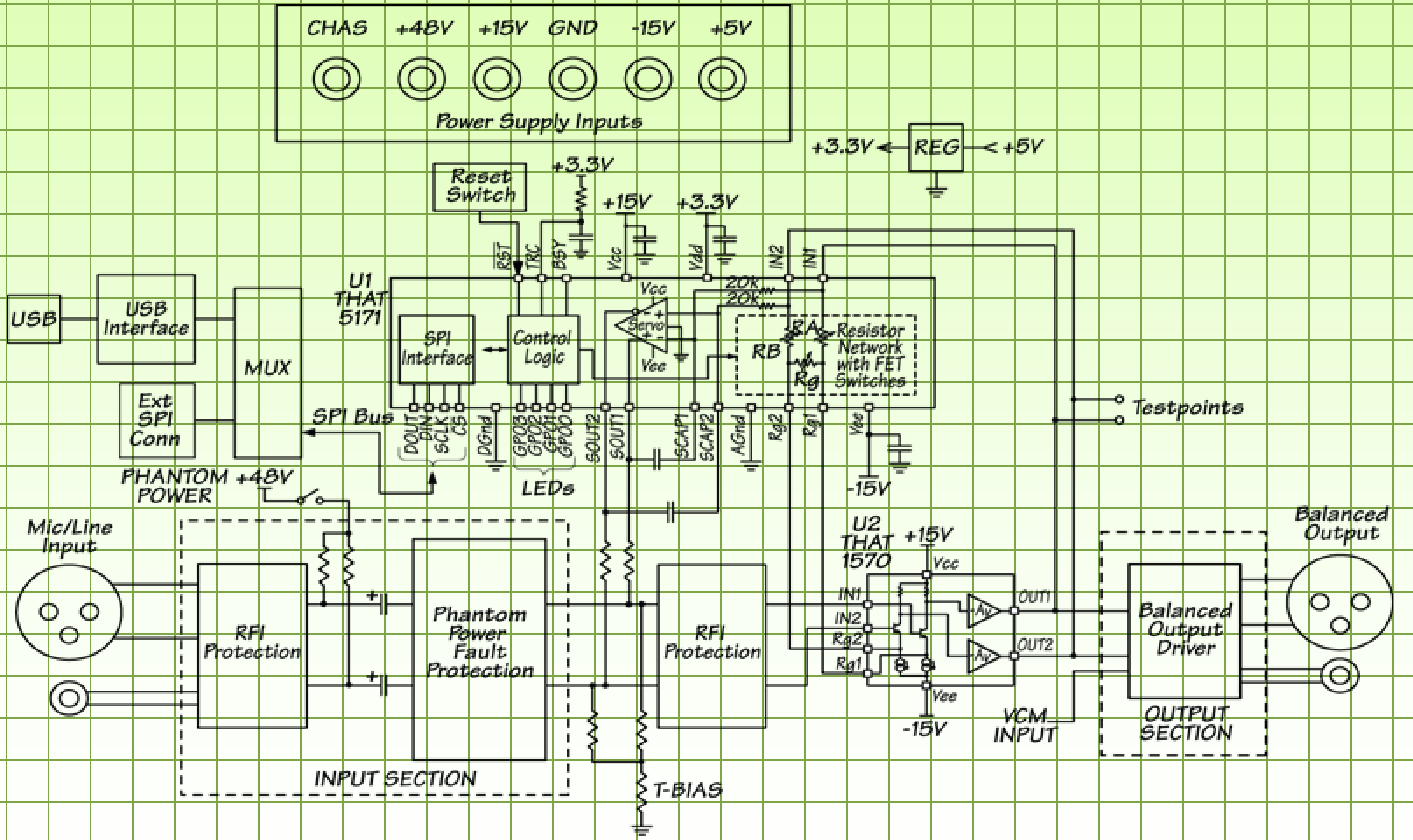
- "0, 8, 9, 10, … 63dB" would be more intuitive, but…
  - Attenuator after mic pre renders absolute numbers meaningless
  - 5.6dB minimum gain optimizes headroom and dynamic range
  - Relative gain steps are 1dB, that's what really matters

1570/5171 Demo Board



1570/5171 Demo Board

- Block Diagram



1570/5171 Demo Board

- GUI controls up to 8 devices
- Connection to PC is USB

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1570/5171 Demo Board

- Specifications

Parameter	Symbol	Typical	Units
Power supply voltage	V+ - V-	±15	V
Maximum input level (V+ /V- = 15V)	V_{IN-BAL}	-21	dBu
Maximum differential output level (V+ /V- = 15V)	V_{OUT}	+21	dBu
Gain (input to output)	A_{dB}	0 8 to 63 in 1 dB steps	dB
Gain error (all settings)	A_{err}	±0.15	dB
Total Harmonic Distortion (V_{OUT} = +16 dBu (5V_{RMS}); R_L = 10kΩ; C_L = 10pF; f = 1kHz; BW = 22 kHz)	THD	0.0003 (0dB gain) 0.0003 (20dB gain) 0.0008 (40dB gain) 0.006 (60dB gain)	%
Equivalent input noise (main output)	EIN	1.65 (60dB gain) 1.9 (40dB gain) 5.0 (20 dB gain) 22.9 (0dB gain)	nV/√Hz
Equivalent input noise (1570 output)	EIN	1.65 (60dB gain) 1.9 (40dB gain) 4.8 (20dB gain) 20 (odB gain)	nV/√Hz
Supply current	I_{CC}; $-I_{EE}$, I_{DD}	23 (V+ supply) 23 (V- supply) 0.5 (+5V supply)	mA

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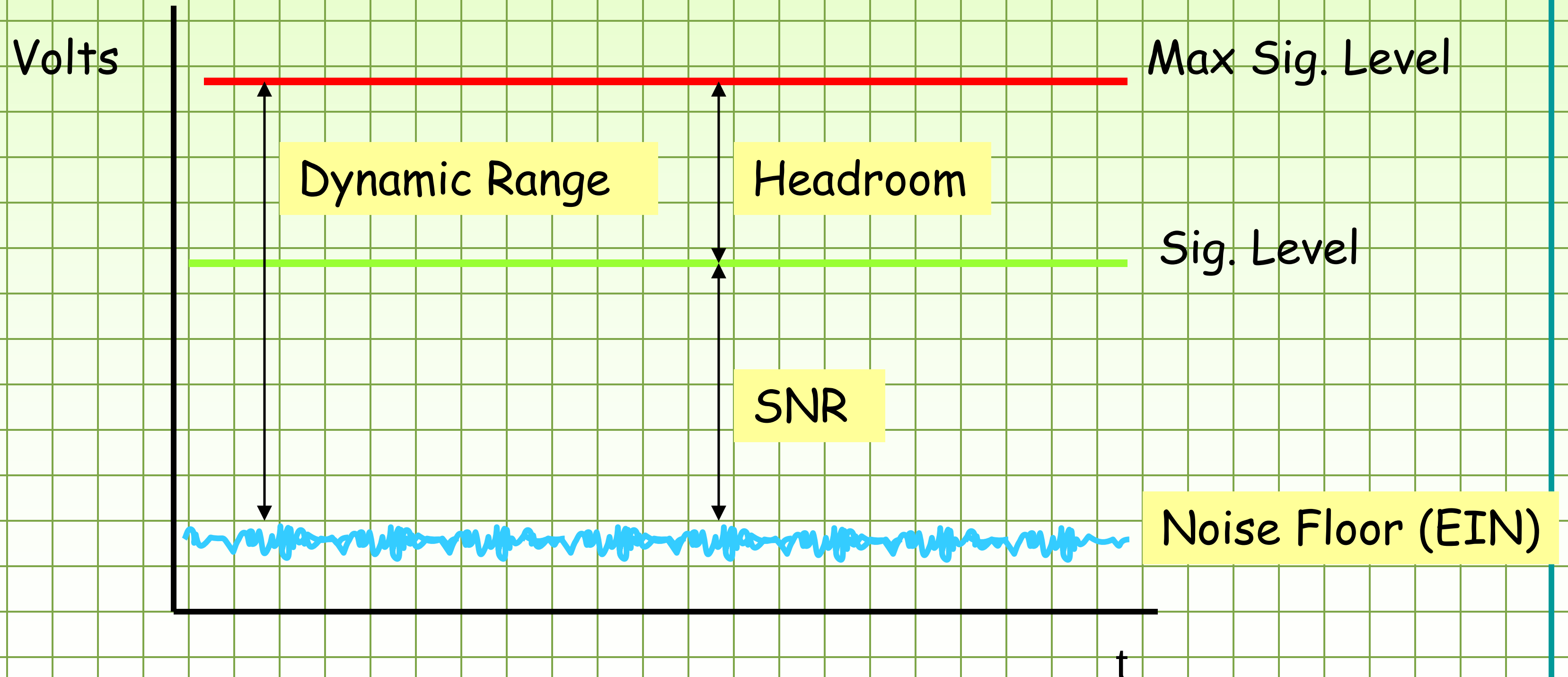
How We Met Customer Demands

- Better Dynamic Range
  - See analysis on forthcoming slides
- Lower Switching Glitches
  - Special (patent pending) FET switches
  - Zero crossing detector with controllable time-out
  - Max gain error = 0.15dB, therefore gain changes are monotonic
  - Reports from the field are that we are "best in class"
- Lower Cost
  - Mix and match 1570, 5171, or your favorite low cost discrete front end
  - 57 accurate gain steps in tiny space for less than the cost of a few analog switch ICs
  - Design Reuse
    - Pump up the volume! Use the same 5171 for ALL your low cost and high performance products!

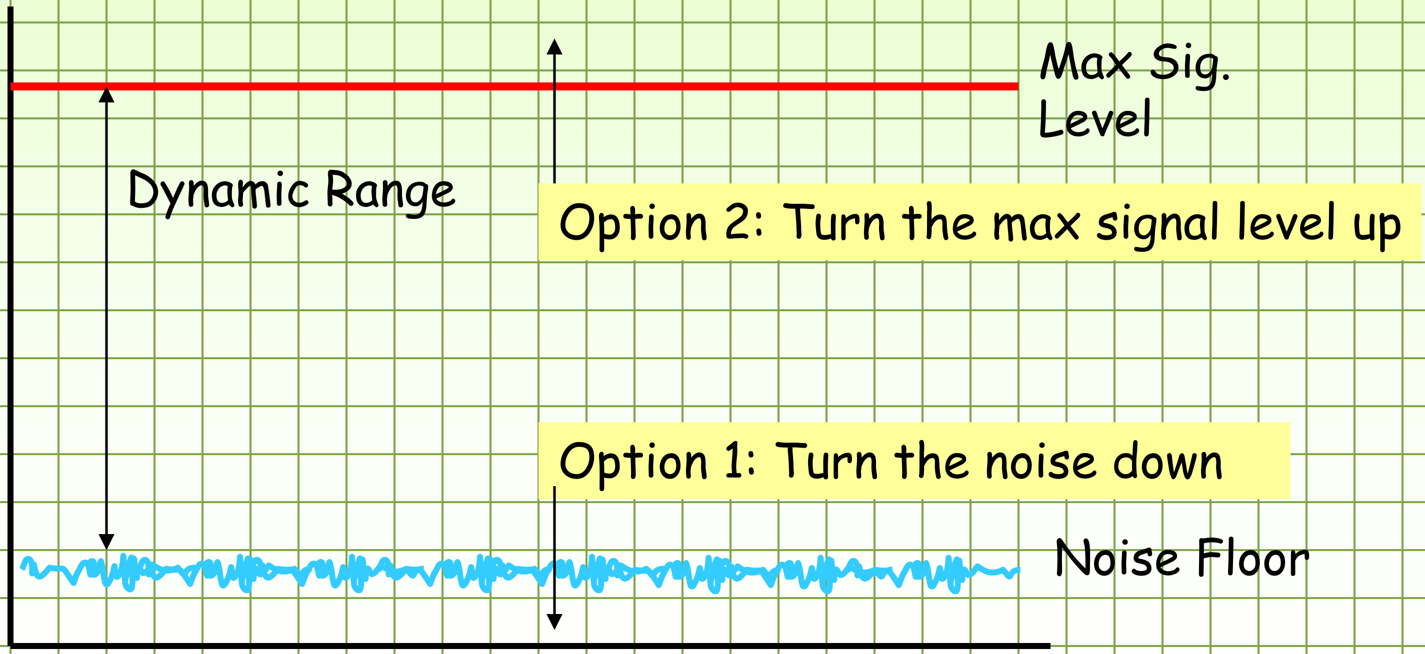
How We Met Customer Demands

- Terminology
- Input headroom critical to prevent clipping from hot signals
- Dynamic Range critical in digital systems (don't waste bits in the ADC!)



How We Met Customer Demands

- Maximizing Dynamic Range
  - Option 1: Turn the noise down
  - Option 2: Turn max sig level (headroom) up



How We Met Customer Demands

- Dynamic Range - Trade Offs
  - Option 1: (turn noise down)
    - Seems obvious, but…
    - 👎 Generally requires higher current consumption
    - 👎 Greater demands on surrounding system (PSRR, low impedances, etc.)
  - Option 2: (turn up the max sig level)
    - 👍👎 Requires higher power supply rails
    - 👍More headroom
  - Option 2 is preferred!

How Much Input Headroom Do We Need?

- Loudest audio sources (SPL)
  - Someone singing loudly: 130dB
  - Guitar amp turned to 11: 140dB
  - Loud orchestral instrument: 155dB
  - Space Shuttle: 180dB
- Mic sensitivity
  - Typically 10-50 mV/Pa
  - Do the math…

Microphone Output Levels

Table 1. Microphone Maximum Output Level (dBu)

Sensitivity		Maximum Sound Pressure Level (Max SPL) @ 1 kHz															
mV/Pa	dBu	120	122	124	126	128	130	132	134	136	138	140	142	144	146	148	150
2	-52	-26	-24	-22	-20	-18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-4	-2	0	2	4
4	-46	-20	-18	-16	-14	-12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	4	6	8	10
6	-42	-16	-14	-12	-10	-8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6	8	10	12	14
8	-40	-14	-12	-10	-8	-6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8	10	12	14	16
10	-38	-12	-10	-8	-6	-4	-2	0	2	4	6	8	10	12	14	16	18
12	-36	-10	-8	-6	-4	-2	0	2	4	6	8	10	12	14	16	18	20
14	-35	-9	-7	-5	-3	-1	1	3	5	7	9	11	13	15	17	19	21
16	-34	-8	-6	-4	-2	0	2	4	6	8	10	12	14	16	18	20	22
18	-33	-7	-5	-3	-1	1	3	5	7	9	11	13	15	17	19	21	23
20	-32	-6	-4	-2	0	2	4	6	8	10	12	14	16	18	20	22	24
22	-31	-5	-3	-1	1	3	5	7	9	11	13	15	17	19	21	23	25
24	-30	-4	-2	0	2	4	6	8	10	12	14	16	18	20	22	24	26
26	-29	-3	-1	1	3	5	7	9	11	13	15	17	19	21	23	25	27
28	-29	-3	-1	1	3	5	7	9	11	13	15	17	19	21	23	25	27
30	-28	-2	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28
32	-28	-2	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28
34	-27	-1	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29
36	-27	-1	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29
38	-26	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
40	-26	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
42	-25	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31
44	-25	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31
46	-25	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31
48	-24	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
50	-24	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32

Max Range

From: http://www.sengpielaudio.com/calculator-transferfactor.htm

Adding some headroom for peaks, mic preamp input must accept ~12-20dBu max input level

Mic Preamp Input Headroom

- Mic pre input needs to handle ~12-20dBu
  - This is why pro audio settled on +/-15V!
- What are we getting today?
  - THAT1510/THAT1512/SSM2019/INA163/etc.:
    - ~24dBu (0dB gain; 1512)
    - ~18dBu (6dB gain)
  - PGA2500 (+/-5V rails)
    - 17.4dBu @ min (0dB) gain
    - 7.4dBu @ first (10dB) gain step
  - THAT 1570/5171 (+/-17V rails)
    - 22dBu @ min (5.6dB) min gain
    - 14dBu @ first (13.6dB) gain step

Input Pads

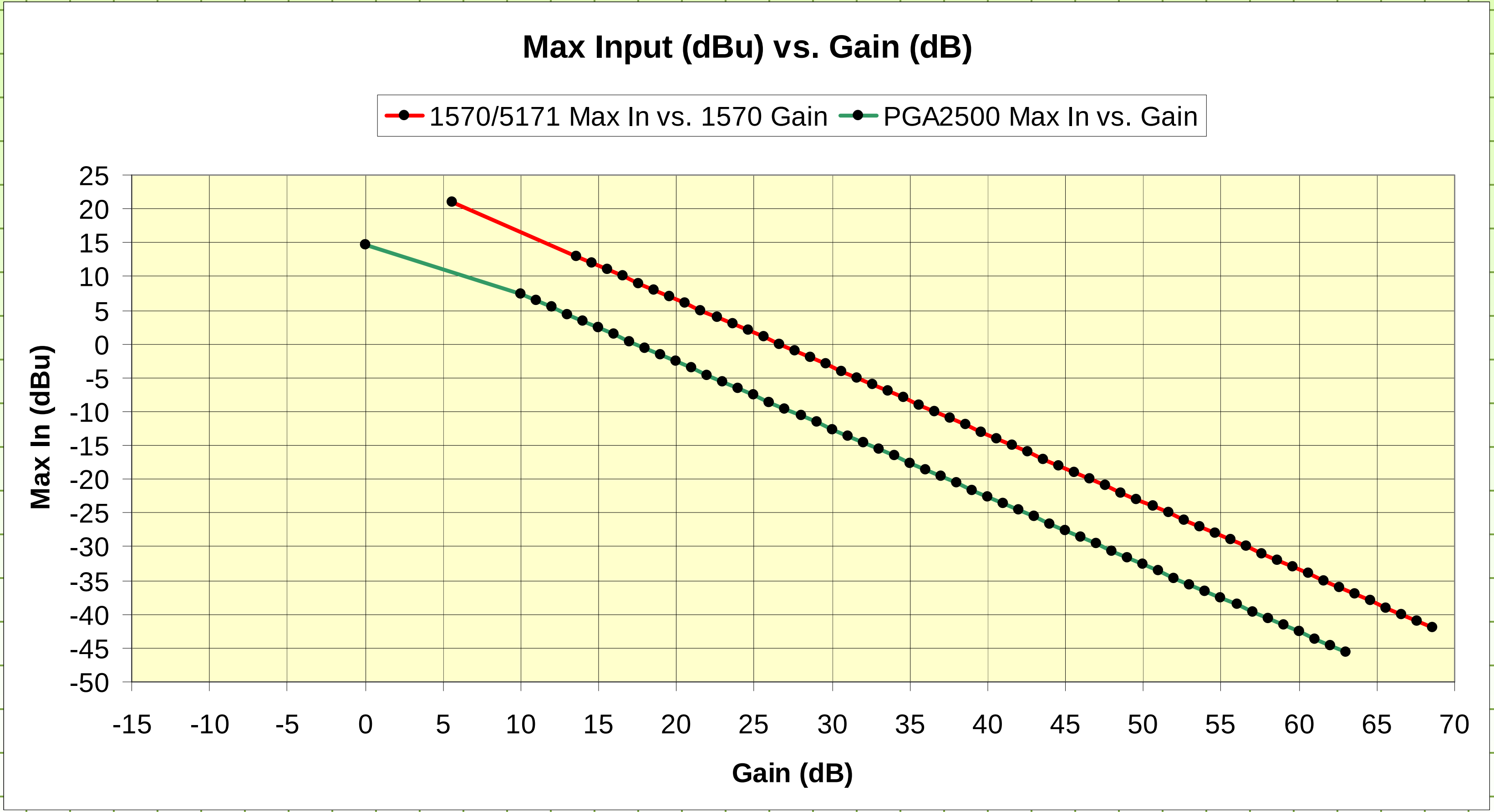
"Pads are evil."

- Anonymous pro audio manufacturer

- Input Pads are Undesirable
  - Cost
  - PCB real estate
  - Degrade Performance (stay tuned…)
- PGA EIN @ 0dB is compromised by 17dB! Don't use the 0dB setting!
- Therefore, PGA is almost always preceded by an input pad
- THAT1570/5171 does not need an input pad

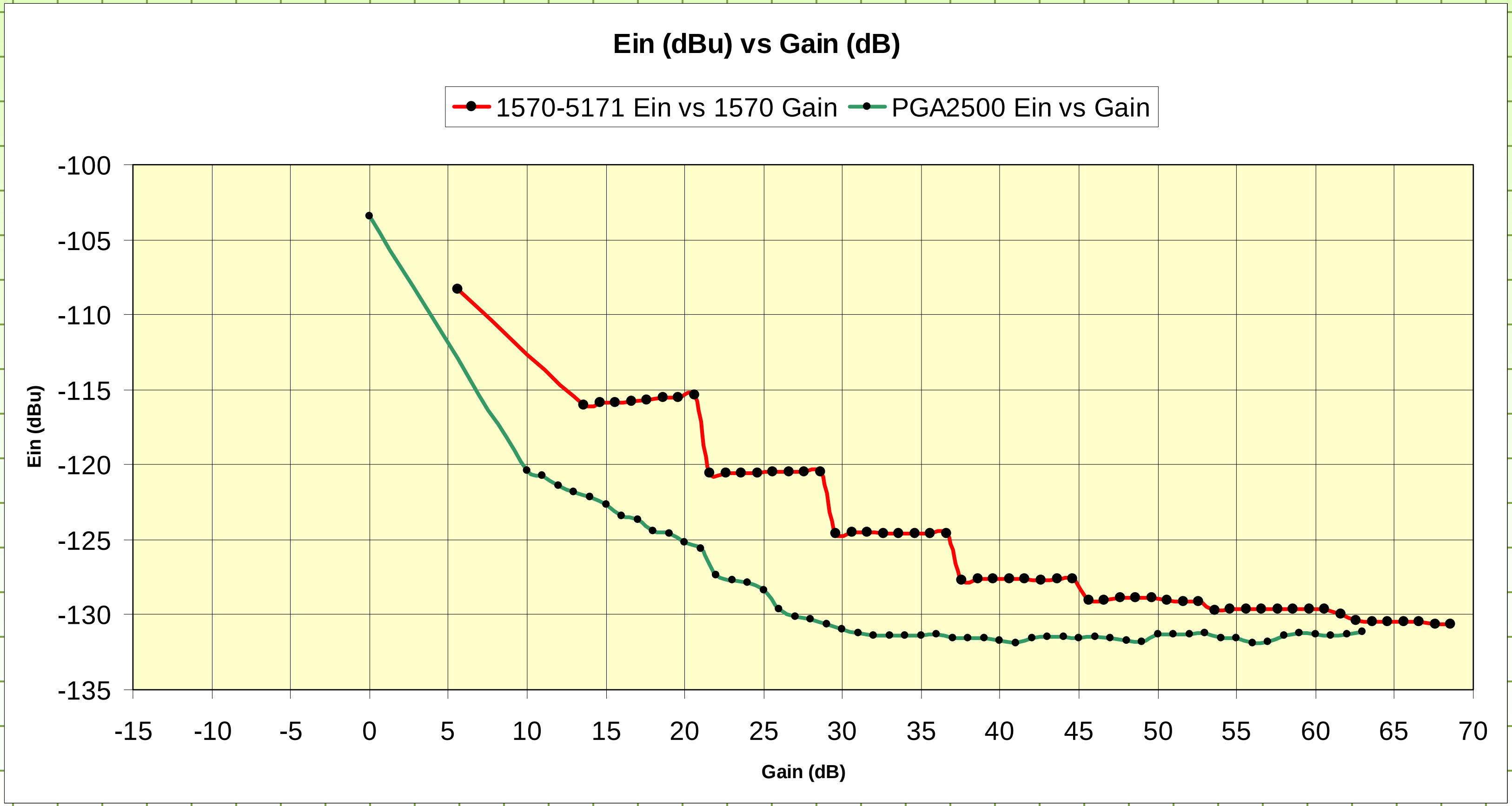
THAT vs PGA - Max Input Level vs Gain

THAT ~10dB more headroom than PGA



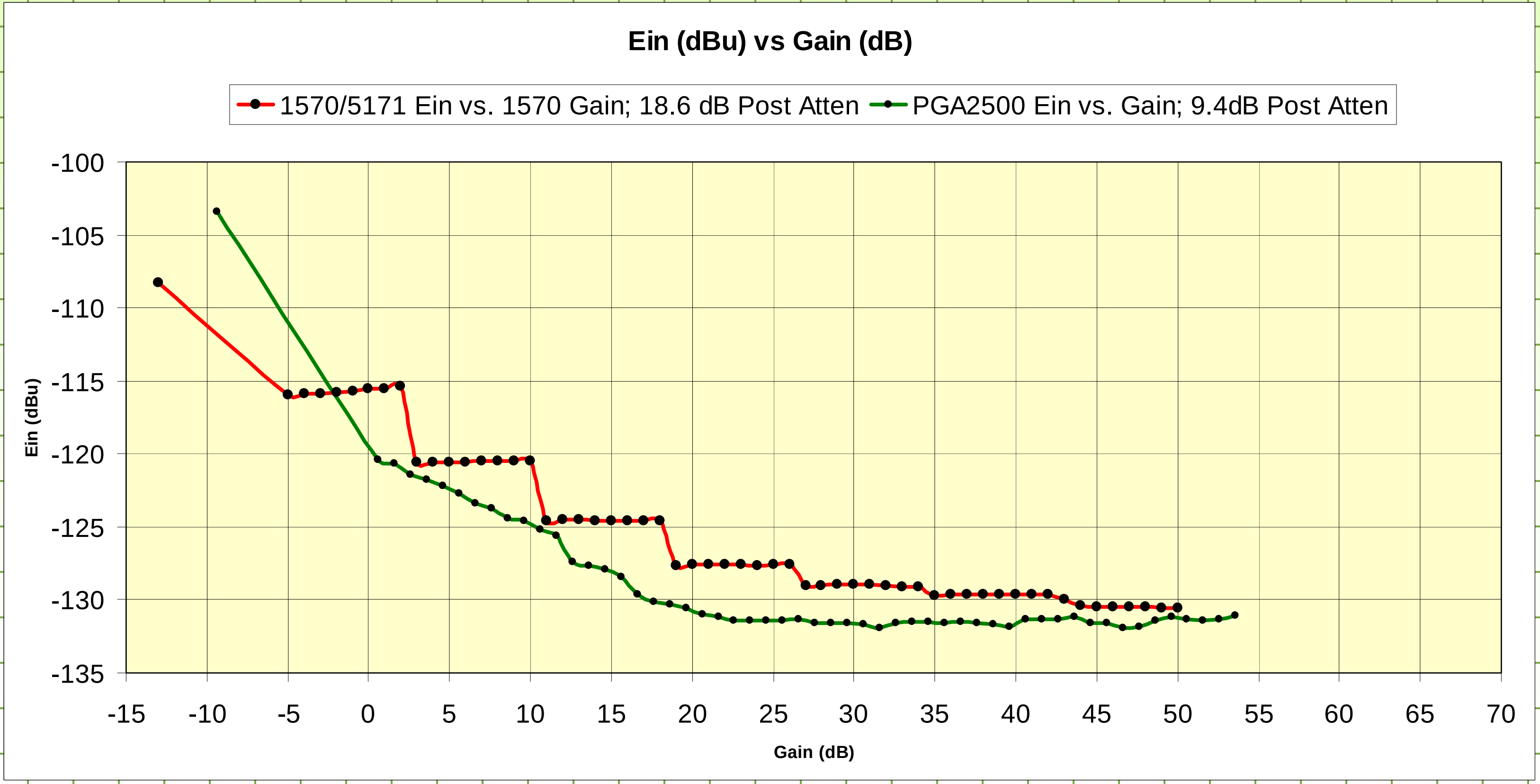
THAT vs PGA - EIN vs Gain

PGA appears ~5dB better than THAT, but…



THAT vs PGA - EIN vs Gain

Add post mic pre attenuator and EIN becomes closer. PGA still seems better, but…



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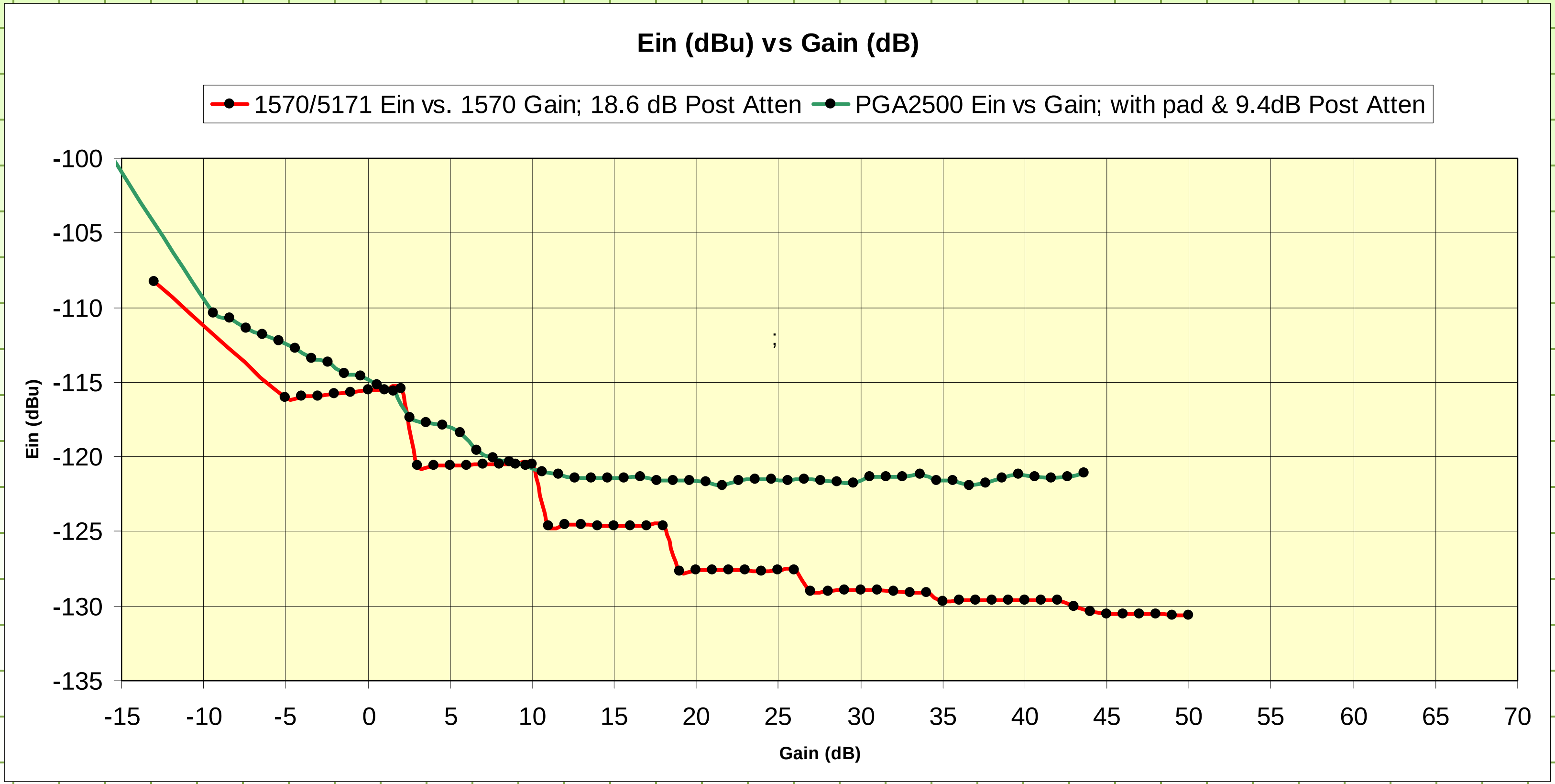
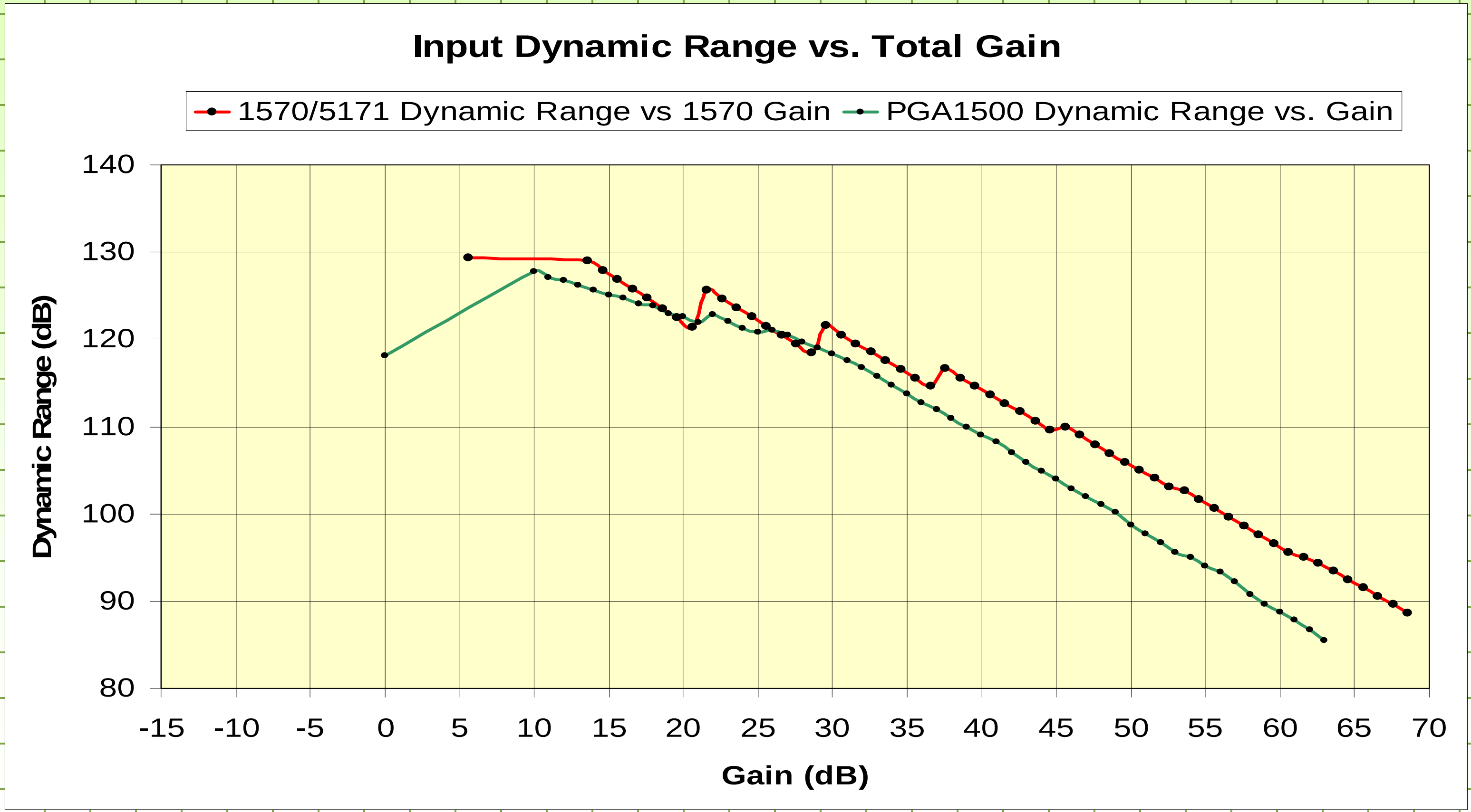
THAT vs PGA - EIN vs Gain

Add input pad (-10dB shown here) and THAT EIN is now lower than PGA.



THAT vs PGA – Dynamic Range vs Gain

No pads, no attenuators. THAT better than PGA.
(Option 2 to improve dynamic range works!)



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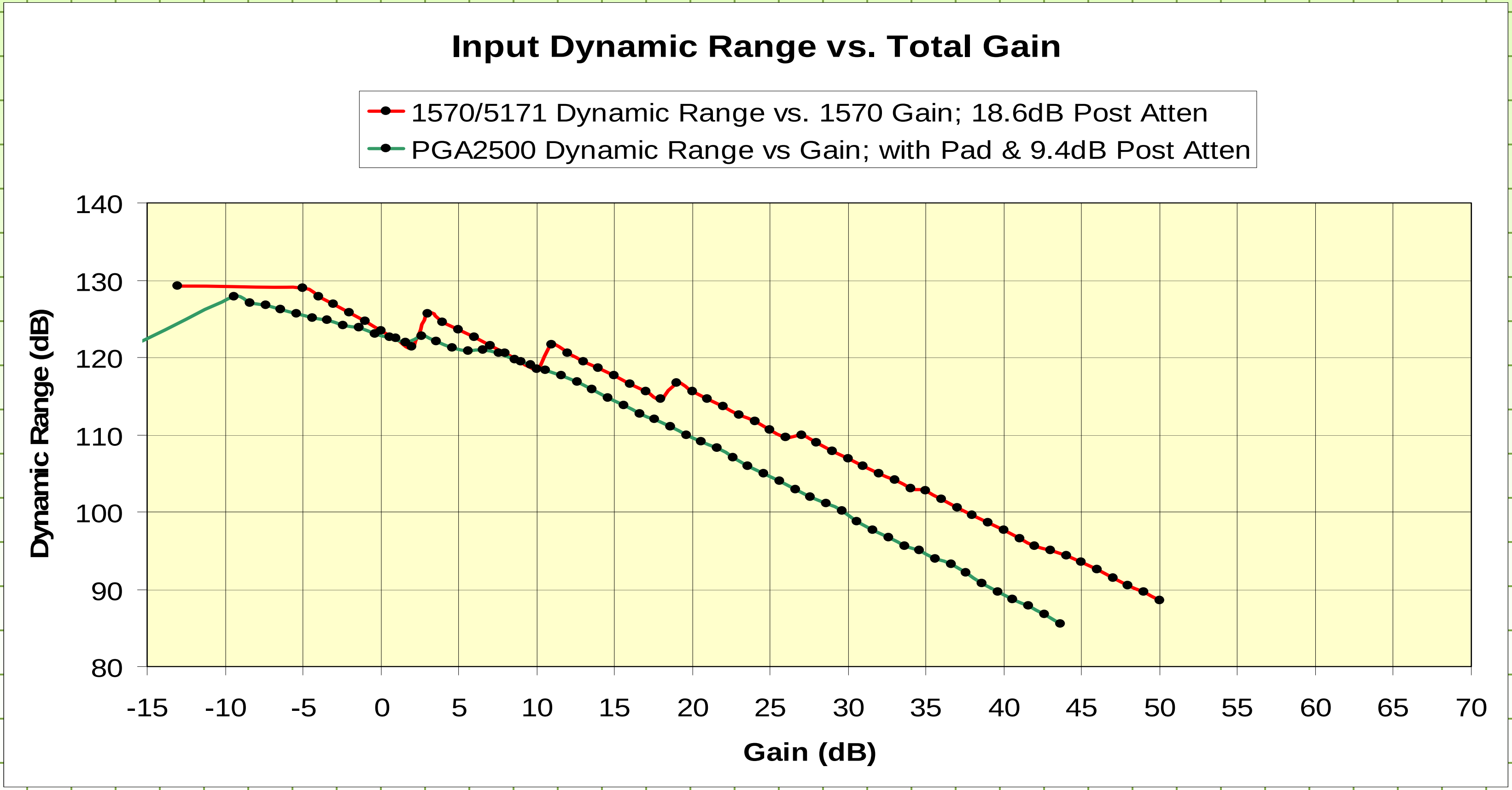
THAT vs PGA – Dynamic Range vs Gain

THAT with Attenuator. PGA with PAD and Attenuator.
THAT better than PGA.



Performance Conclusions

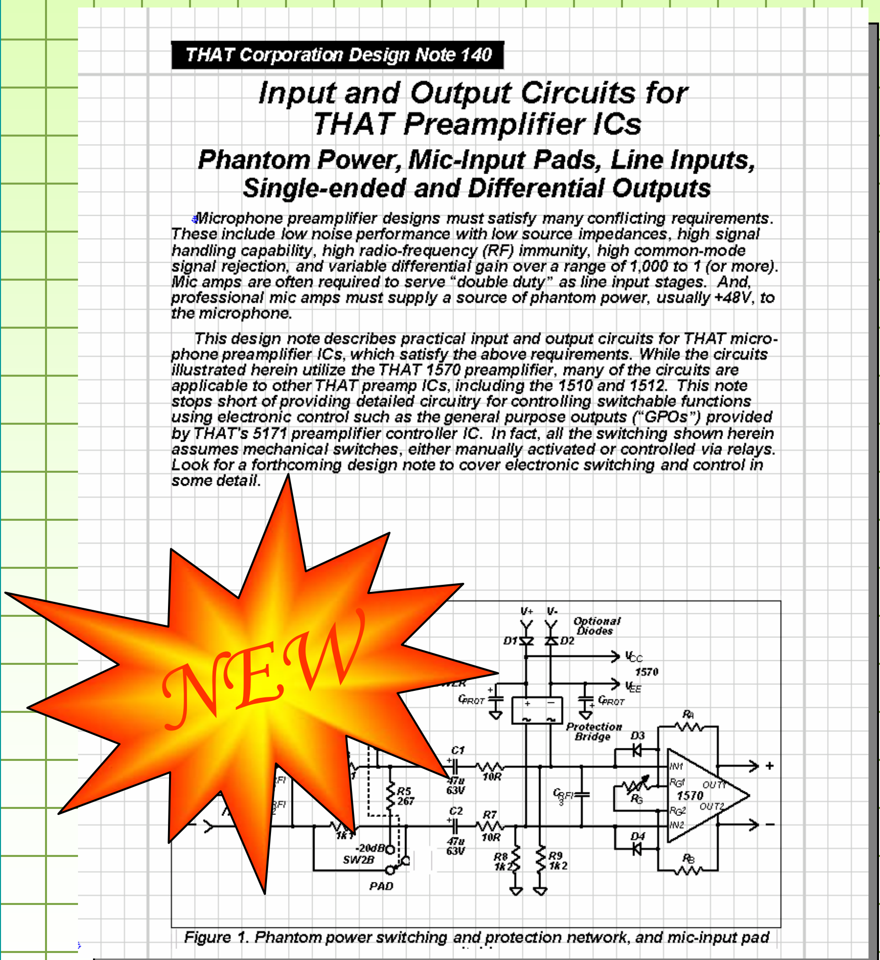
- Input Headroom
  - THAT1570/5171 much better than PGA
  - PGA needs a pad, which kills EIN
- EIN
  - PGA slightly better than THAT 1570/5171 with no pad
  - THAT with no pad better than PGA with pad
- Dynamic Range
  - THAT better than PGA
- Power Consumption
  - By the way, PGA ~2X power of THAT

Bonus: THAT Corp Legendary Support

- THAT engineers have many decades experience in pro audio, and no experience making cell phones
- THAT routinely advises customers on design/PCB layout.
- Please let us help you!

Bonus: THAT Corp Legendary Support

- DN140 - New Mic Pre Design Note!


THAT Corporation Design Note 140

Input and Output Circuits for THAT Preamplifier ICs

Phantom Power, Mic-Input Pads, Line Inputs, Single-ended and Differential Outputs

Microphone preamplifier designs must satisfy many conflicting requirements. These include low noise performance with low source impedances, high signal handling capability, high radio-frequency (RF) immunity, high common-mode signal rejection, and variable differential gain over a range of 1,000 to 1 (or more). Mic amps are often required to serve "double duty" as line input stages. And, professional mic amps must supply a source of phantom power, usually +48V, to the microphone.

This design note describes practical input and output circuits for THAT microphone preamplifier ICs, which satisfy the above requirements. While the circuits illustrated herein utilize the THAT 1570 preamplifier, many of the circuits are applicable to other THAT preamp ICs, including the 1510 and 1512. This note stops short of providing detailed circuitry for controlling switchable functions using electronic control such as the general purpose outputs ("GPOs") provided by THAT's 5171 preamplifier controller IC. In fact, all the switching shown herein assumes mechanical switches, either manually activated or controlled via relays. Look for a forthcoming design note to cover electronic switching and control in some detail.

Figure 1. Phantom power switching and protection network, and mic-input pad

Mic Preamp Circuits
- Phantom Power
- Input pads
- Line Inputs
- Outputs

More Information

- http://www.thatcorp.com/digmicpre
  - Latest datasheets, design notes
- support@thatcorp.com
  - Technical support
- sales@thatcorp.com
  - Samples, demo boards