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Department Engineering

Subject **Analog Secrets Your Mother Never Told You**

Name Les Tyler, Gary Hebert, Ros Bortoni, Bob Moses

Address 123rd AES Convention
New York, October 2007

Seminar Outline

- New ICs
- Microphone preamplifiers
- Log math
- Balanced outputs
- Q & A
- Door prizes!

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Chapter **New ICs**

Name Bob Moses

Address 123rd AES Convention
New York, October 2007

New ICs

- THAT 2162 Dual VCA
  - Pre-trimmed
  - Current-in, current-out
  - VCAs are completely independent
  - QSOP-16 package
  - $2.98 (1,000's) -- $1.49 per channel
  - Samples available now
  - Production quantities this quarter (4Q07)

New ICs

- THAT 1280-Series
  Dual Balanced Line Receiver
  - Three gain versions
    - THAT 1280: 0dB (pin compatible w/ TI INA2134)
    - THAT 1283: ±3dB
    - THAT 1286: ±6dB (pin compatible w/ TI INA2137)
  - SO-14 package
  - $1.98 (1,000's) -- $0.99/channel
  - Samples available now
  - Production quantities this quarter (4Q07)

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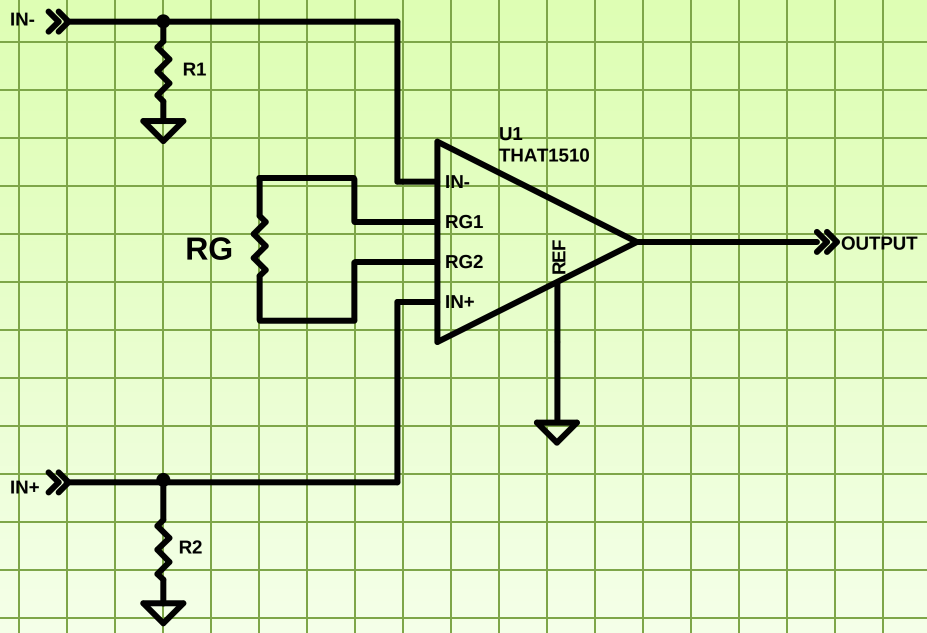
Chapter **Mic Preamps**

Name Rosalfonso "Ros" Bortoni

Address 123rd AES Convention
New York, October 2007

Mic Preamp – Highlights

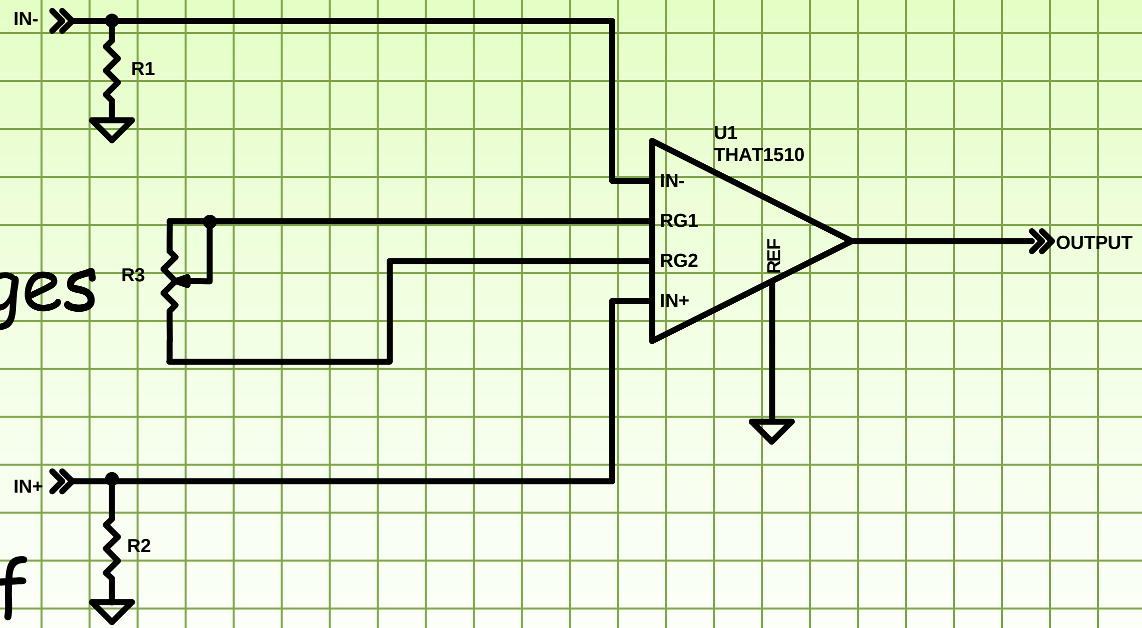
- One chip solution
  - Wide gain range
  - High bandwidth
  - Low noise
  - Low power



- Two gain options
  - 1510: G = 1 + 10k/Rg (0dB min)
  - 1512: G = 0.5 + 5k/Rg (-6dB min)
    - Accepts +24dBu @ +/- 15V rails

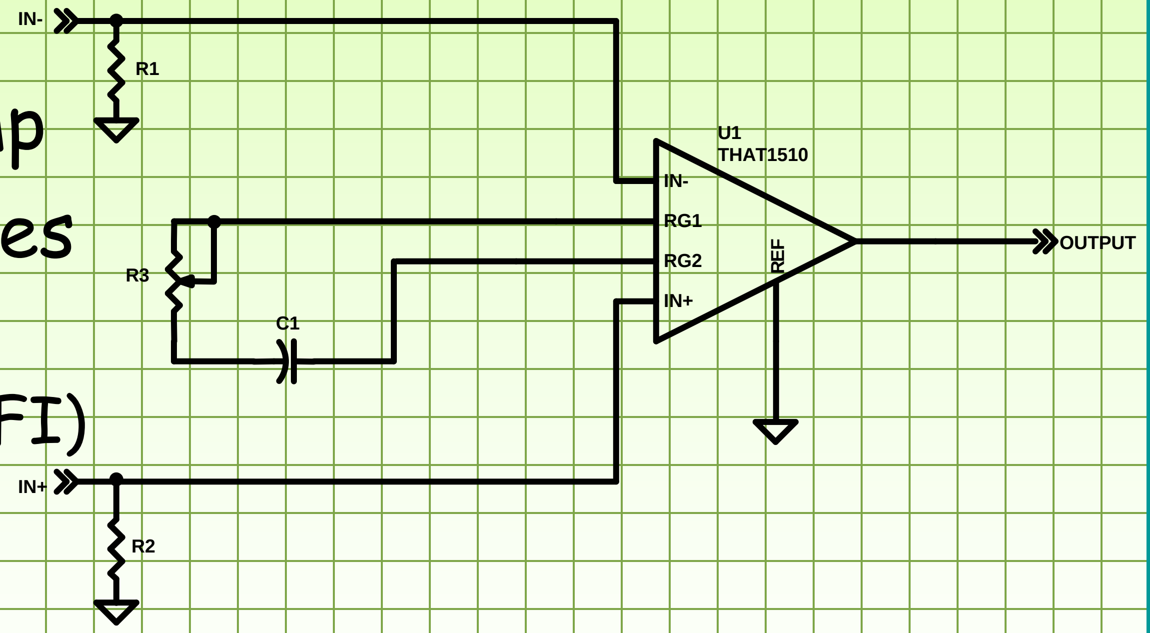
Continuously Adjustable Gain Mic Preamp

- Uses potentiometer (R3) to control gain
- 60dB+ gain range
- Output dc offset changes with gain
- Will thump if changed quickly



Cure Thump with a Capacitor

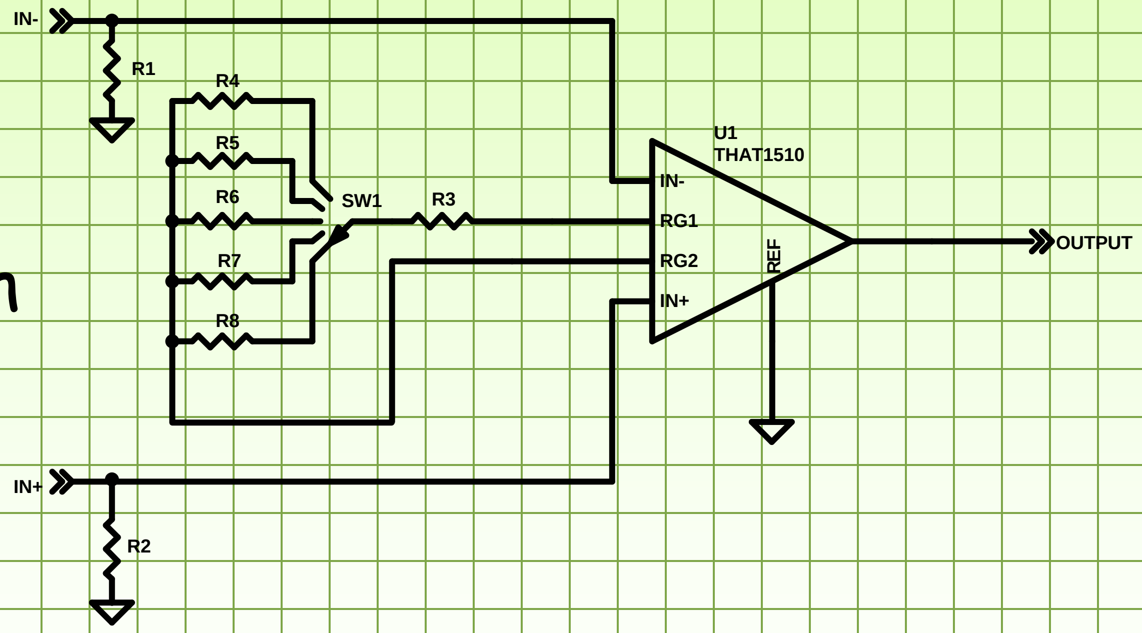
- C1 avoids output dc variations
- Sets dc gain to 1



- Avoids thump
- Disadvantages
  - + PCB Area
  - Antenna (RFI)
  - Cost of cap

Switched Gain Mic Preamp

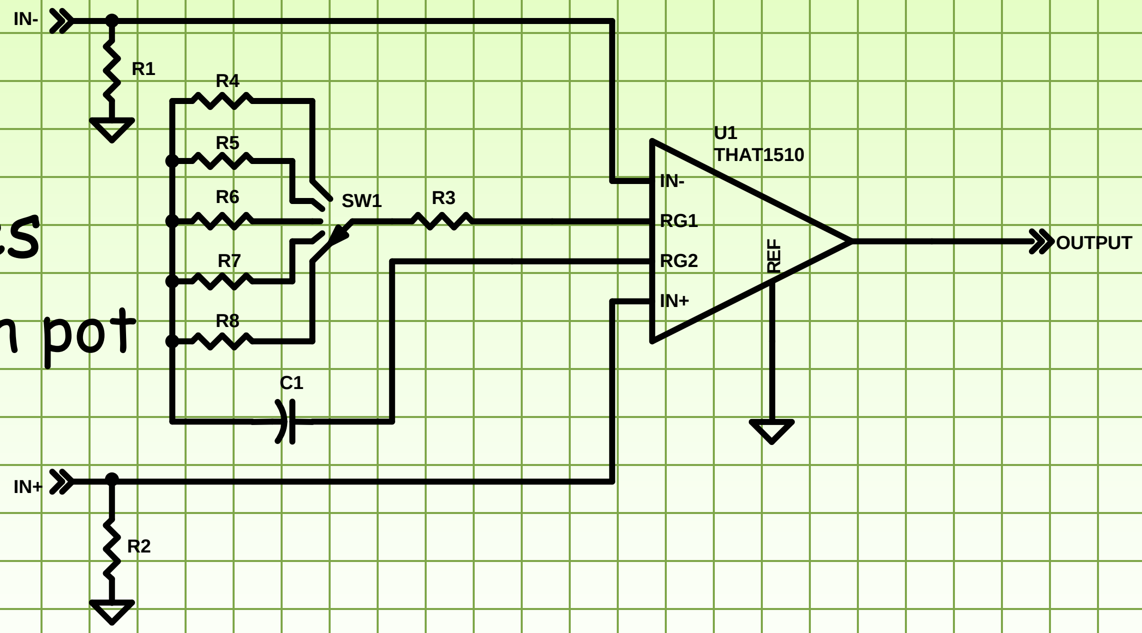
- Uses switches to control gain
- 60dB+ gain range
- Output dc offset still changes with gain



- Will click when gain is changed

Cure Click with a Capacitor

- C1 avoids output dc variations
- Sets dc gain to 1
- Avoids click
- Disadvantages
  - Same as with pot

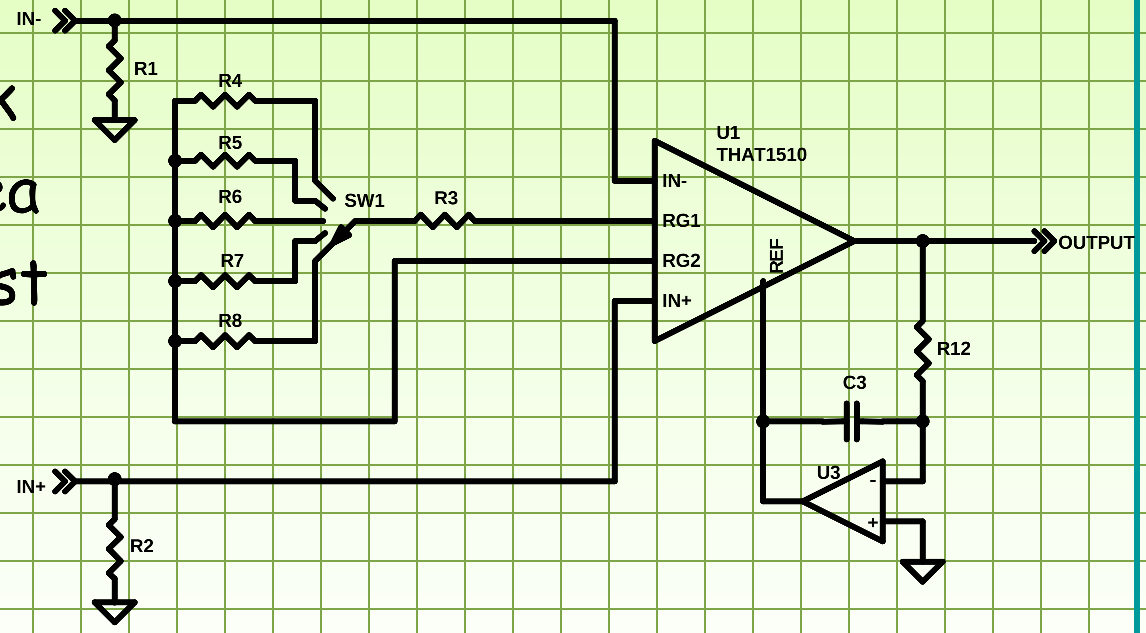


Mic Preamps – Choosing the Cap

- First, choose minimum Rg based on max gain
- Second, choose highest allowed LF cutoff
- Then: $Cg = 1 / (2\pi fRg)$
- For max gain = +60dB & LF cutoff = 5Hz
  - For 1510: Rg = 10Ω, $Cg \cong$ 3300µF
  - For 1512: Rg = 5Ω, $Cg \cong$ 6800µF
- For max gain = +40dB & LF cutoff = 5Hz
  - For 1510: Rg = 100Ω, $Cg \cong$ 330µF
  - For 1512: Rg = 50Ω, $Cg \cong$ 680µF
- Etc.

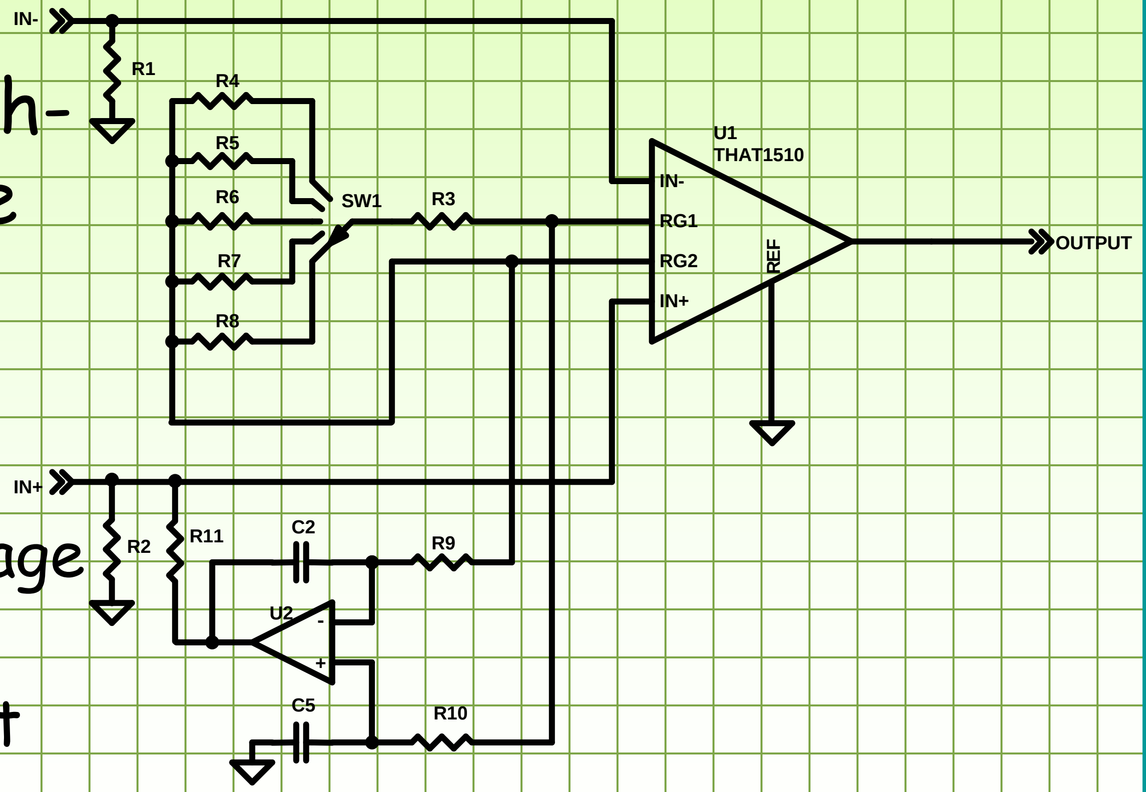
Mic Preamp with Output Servo

- Reduces steady-state output offset
- Doesn't fix transient offset
  - Likely to click
  - Adds PCB area
  - Increases cost



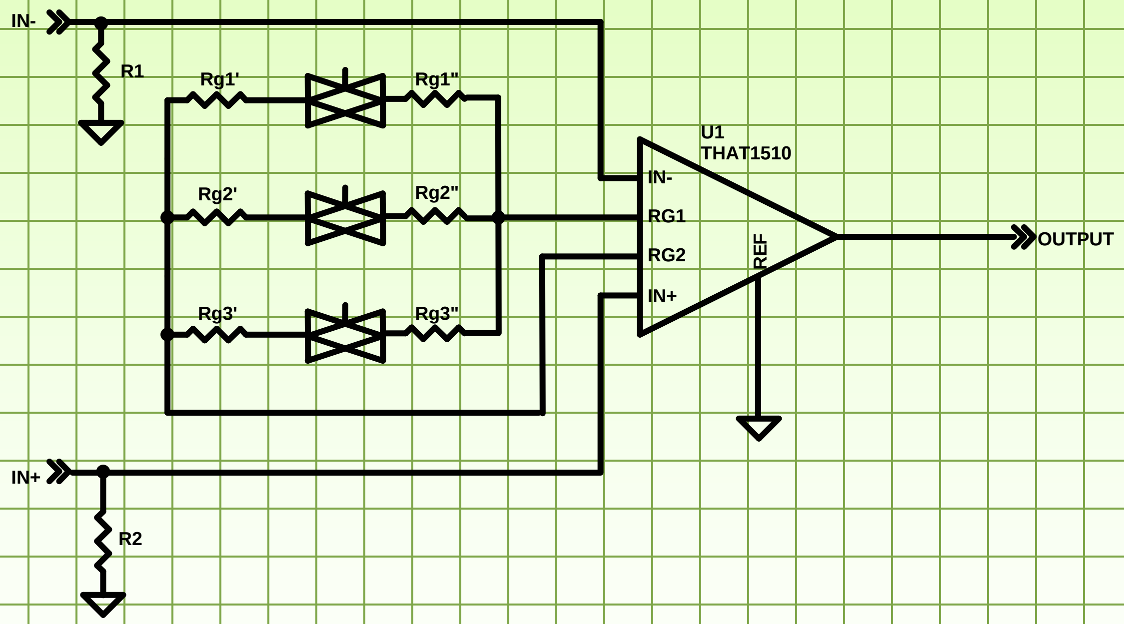
Mic Preamp with Input Servo

- Reduces steady-state output offset
- Reduces transient offset, too
- Requires high-performance opamp
  - Low input offset voltage
  - Low input bias current



Recommended Circuit for Digital Control

- Use C-MOS switches to change Rg
- Splitting Rg to minimize charge injection (pops)



- 1512 lowers charge injection pop by 6dB

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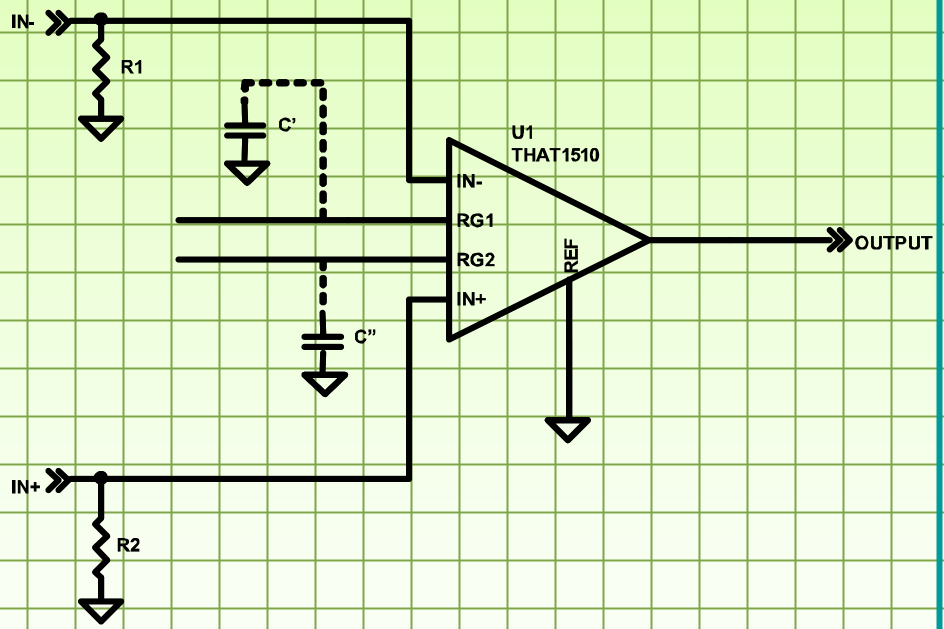
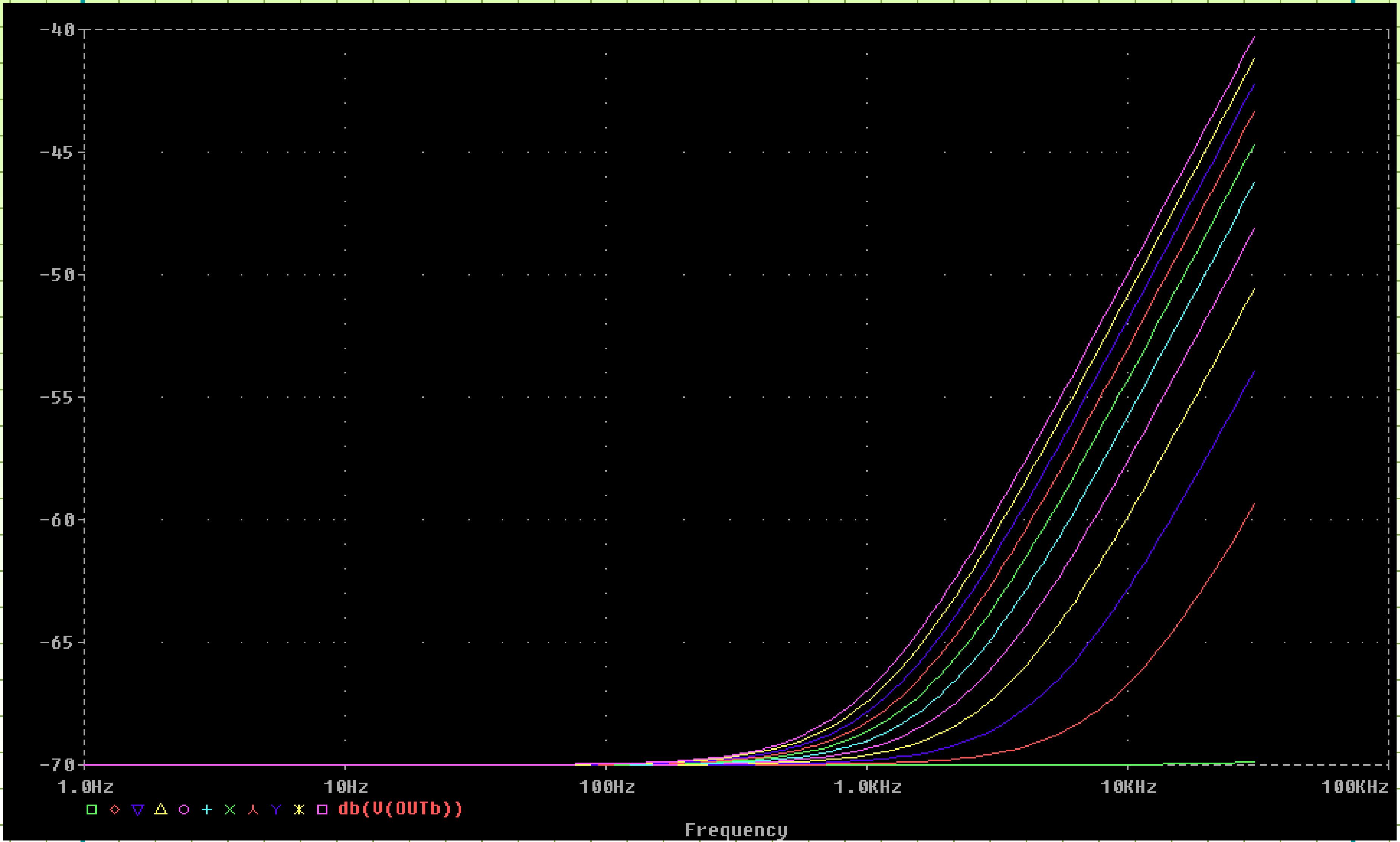
Unbalanced Capacitance at Rg1, Rg2

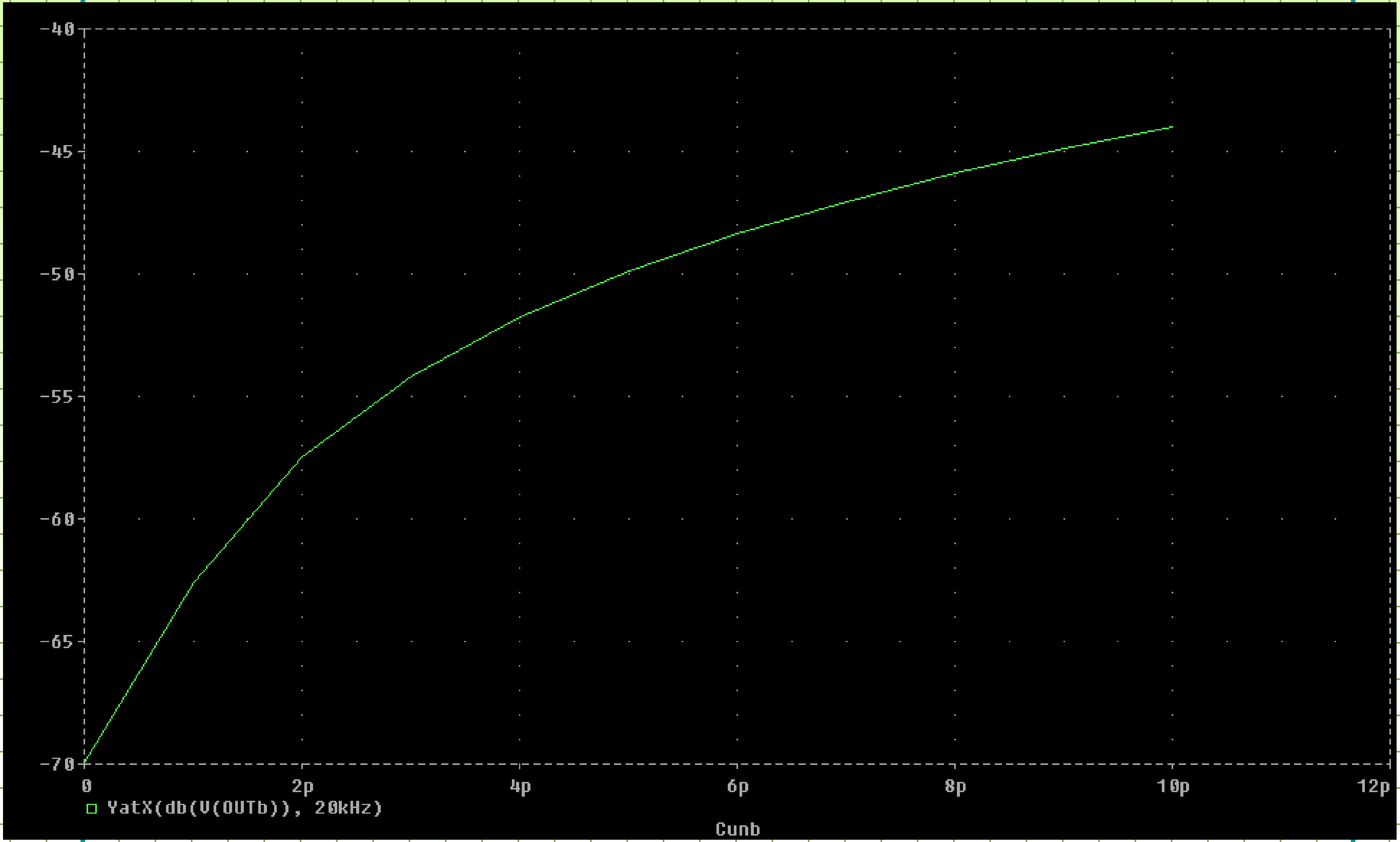
- Lowers CMRR @ HF
- Caused by
  - PCB stray capacitances
  - Different loading on Rg1 vs Rg2
- Effect is surprisingly large



Common-Mode Gain vs. Freq., 1~10pf Imbalance



Common-Mode Gain vs. Capacitive Imbalance, 20kHz



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Chapter *VCA/RMS & Log Math*

Name Les Tyler

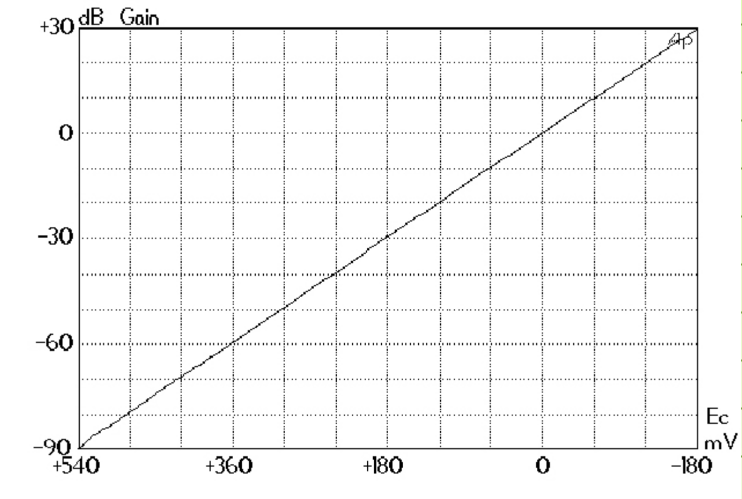
Address 123rd AES Convention
New York, October 2007

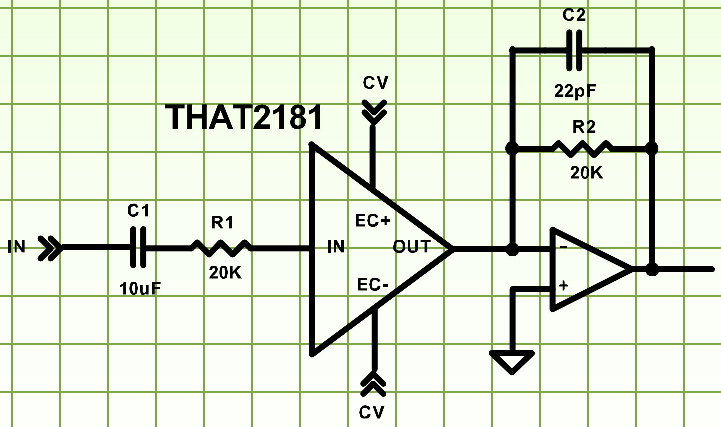
THAT VCAs, RMS, & Log Math

- (Very) basic Voltage Controlled Amplifiers (VCAs)
- (Very) basic RMS Detectors
- (Very) basic Analog Engines®
- Cool "log math" simplifies designs using the above

Blackmer® VCAs Offer "Deci-Linear" Control

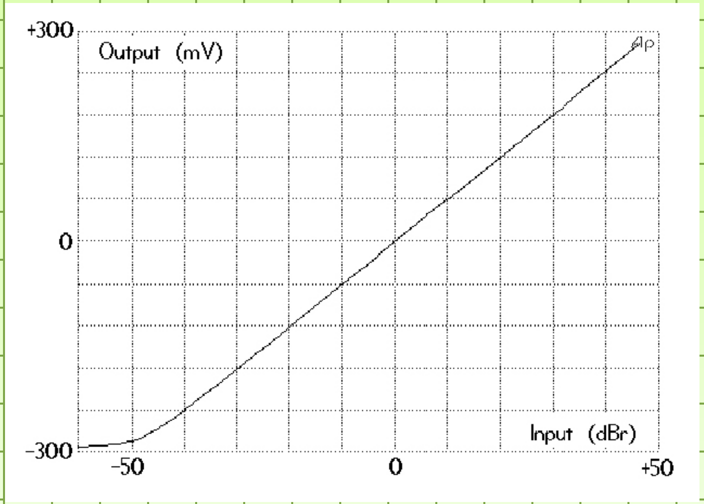
- *Linear* control voltage causes *Exponential* gain (direct dB control)
- Typically -100~+40dB
- ~ ±6mV per dB gain
- Positive- & negative-sense control ports
- Current in & out
- Singles: 2180/1-series
  - SO-8 & SIP-8
- Dual: 2162
  - QSOP-16

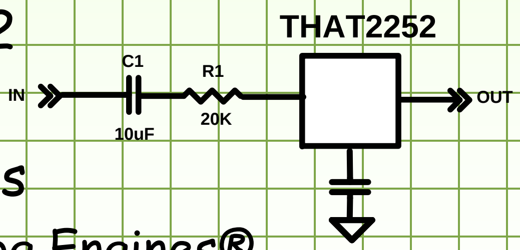


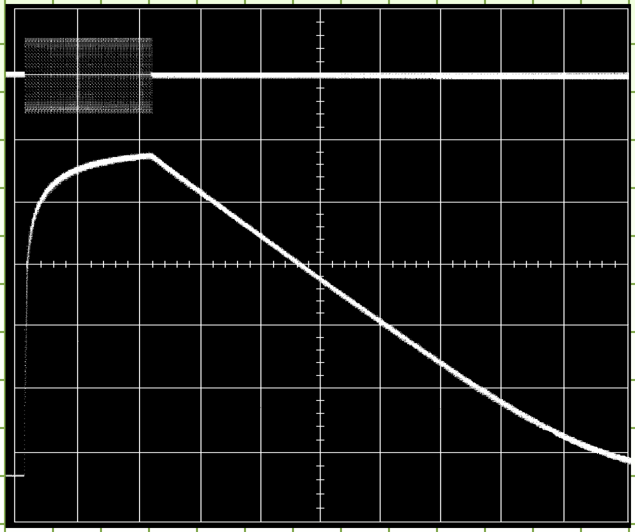


THAT Level Detectors Are "Deci-Linear"

- Logarithmic output Voltage (direct dB) reading
- Good linearity over >60dB
- Current in, voltage out
- RMS-responding
- Time response mimics ear's time-weighting
  - Less sensitive to phase shifts than peak or average.
- Single: 2252
  - SIP-8
- SO-packages
  - See Analog Engines®

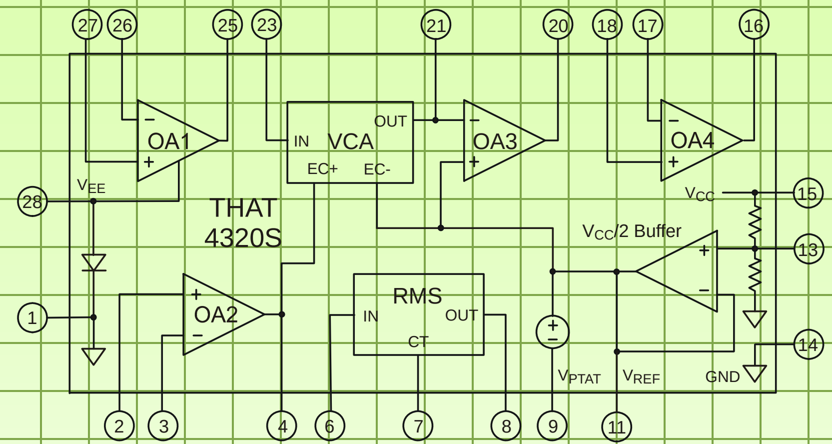


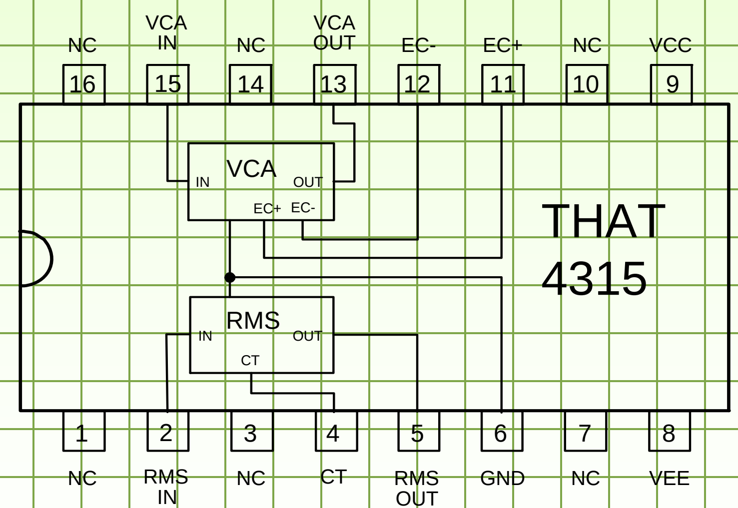




Analog Engines®: VCAs + RMS Detector

- Compressor/limiter *on a single chip*
- Versatile 4320/4301
  - Includes several opamps and other useful stuff
- Basic 4305/4315
  - Just VCA and RMS detector
- 4301/4305
  - High voltage (±15V)
- 4315/4320
  - Low voltage, low power (+5V, 1.6mA)





Analog Engines® Are Deci-Linear, Too

- VCAs offer Deci-Linear control law
  - Direct dB control of gain
- Detectors offer Deci-Linear output law
  - Direct dB reading of RMS level
- Makes designing complex dynamics processors easy
  - Compressors/Limiters
  - Expanders/Gates
- Feedforward possible
  - VCA control law matches RMS-detector output law
- Deci-Linear characteristic makes "log-math" useful for side chain design
- Easily produces repeatable, predictable results

Linear Math Approach

- VCA gain law: $A_V = e^{\frac{-E_C}{2V_T}}$

- Detector output law: $V_{OUT} = 2V_T \ln(V_{inrms})$

- "Linear" math leads to exponentials & logs
- Combining these two *theoretically* predicts gain trajectory
- But, do you really want to deal with this math?

"Log Math" Approach

- Express signal levels as their dB levels
- Express all gains in dB

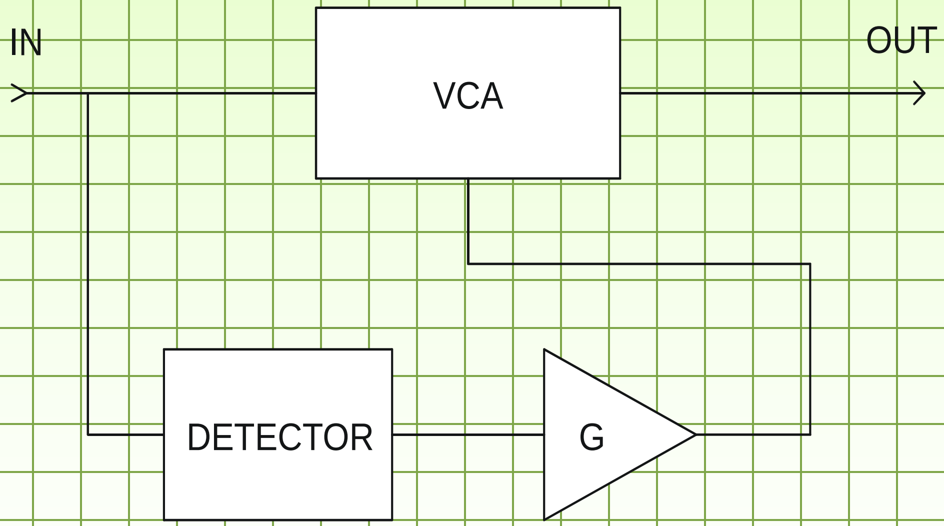
- VCA gain law: $A_{db} = -166.7E_c$
- Detector output law: $V_{OUT} = 0.006\,dB_{RMS}$

- "Log" math reduces the exponentials and logs to simple, linear relationships
- Much easier to deal with!

Feedforward Processors – Log Math

- We can combine the previous two equations, and get:

$$dB_{OUT} = dB_{IN} + [-166.7 \bullet (G \bullet 0.006\, dB_{IN})] = (1-G)\, dB_{IN}$$

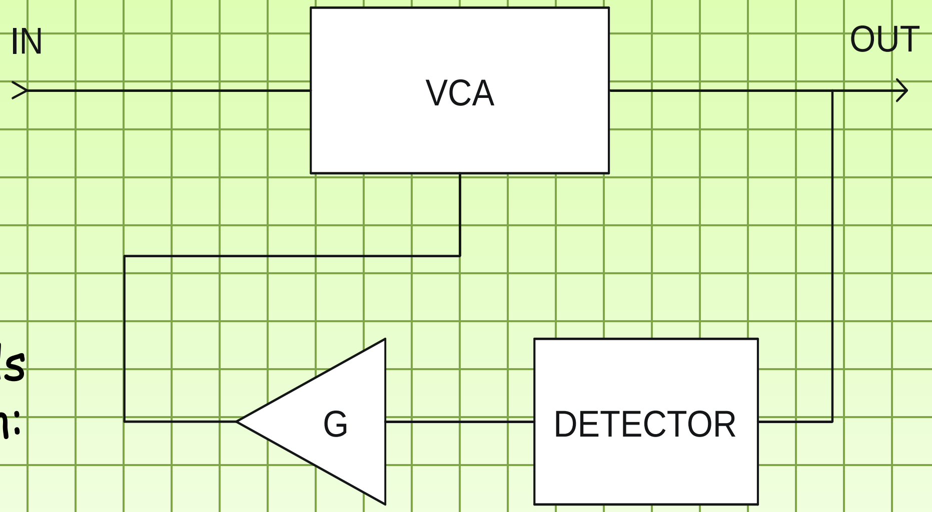


- Compression (Expansion) ratio is:

$$\frac{dB_{IN}}{dB_{OUT}} = \frac{1}{(1-G)}$$

- Sign of gain determines compress or expand
- Lots of variations possible
  - Infinite compression
  - Negative compression

Feedback Processors – Log Math



- The VCA control voltage depends on the detector's level reading and G:

$$E_C = G \bullet 0.006\,dB_{OUT}$$

- But, the output signal depends on the input and the VCA gain:

$$dB_{OUT} = dB_{IN} + [166.7 \bullet (G \bullet 0.006 dB_{OUT})] = dB_{IN} - G dB_{OUT}$$

- Combining and rearranging, we can solve for the Compression (or Expansion) ratio:

$$\frac{dB_{IN}}{dB_{OUT}} = 1 + G$$

- Sign of gain G determines compress vs. expand
- Fewer variations are possible due to stability considerations
  - Infinite compression is unstable!

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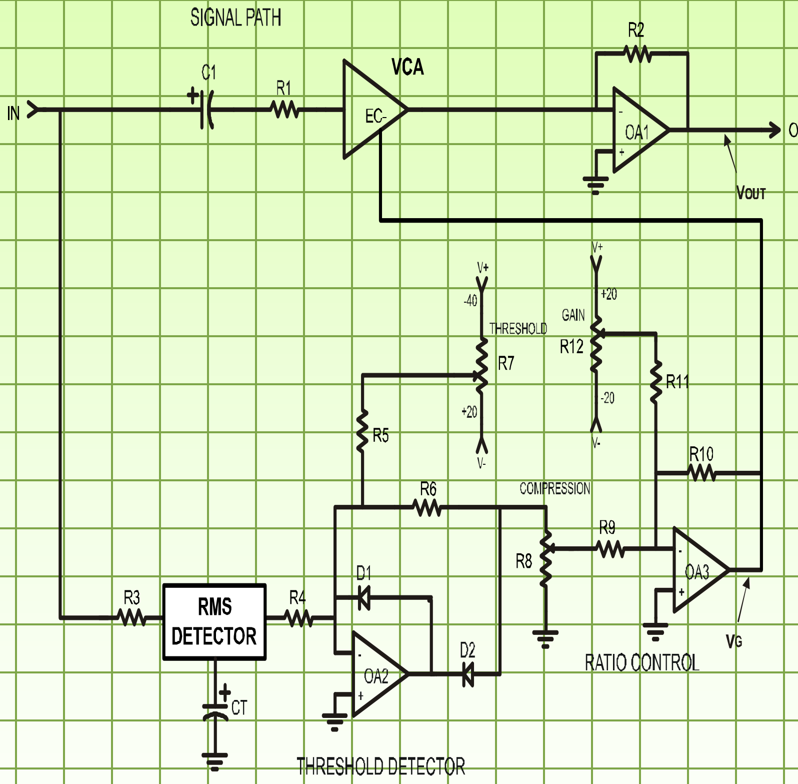
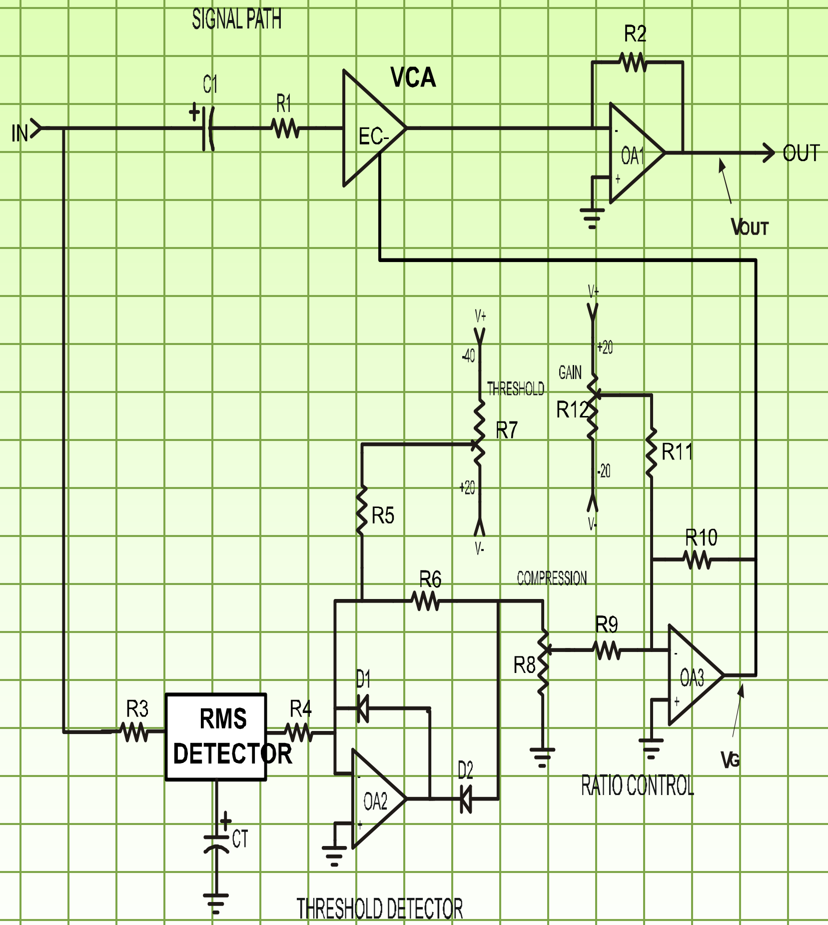
Adding Thresholds

- Change G based on detector's output level
  - Half-wave rectifier
  - OA2/D1/D2
- Vary dc offset (R7) before rectifier
  - Changes the "active region" where detector's output passes to the VCA control port
  - Corresponds to a dB threshold



Controlling Ratio and Static Gain

- Vary control path gain (R8)
  - Changes G (in the active region)
  - Controls compression/ expansion ratio
- Vary dc offset (R12) after clamp circuit
  - Changes static gain



See THAT's app notes for more detail

- AN101a: details about "Log math" involved
- AN100a: side-chain circuit details
  - Compressor application
- Many others for more circuit ideas

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Subject **Balanced Outputs**

Name Gary Hebert

Address 123rd AES Convention
New York, October 2007

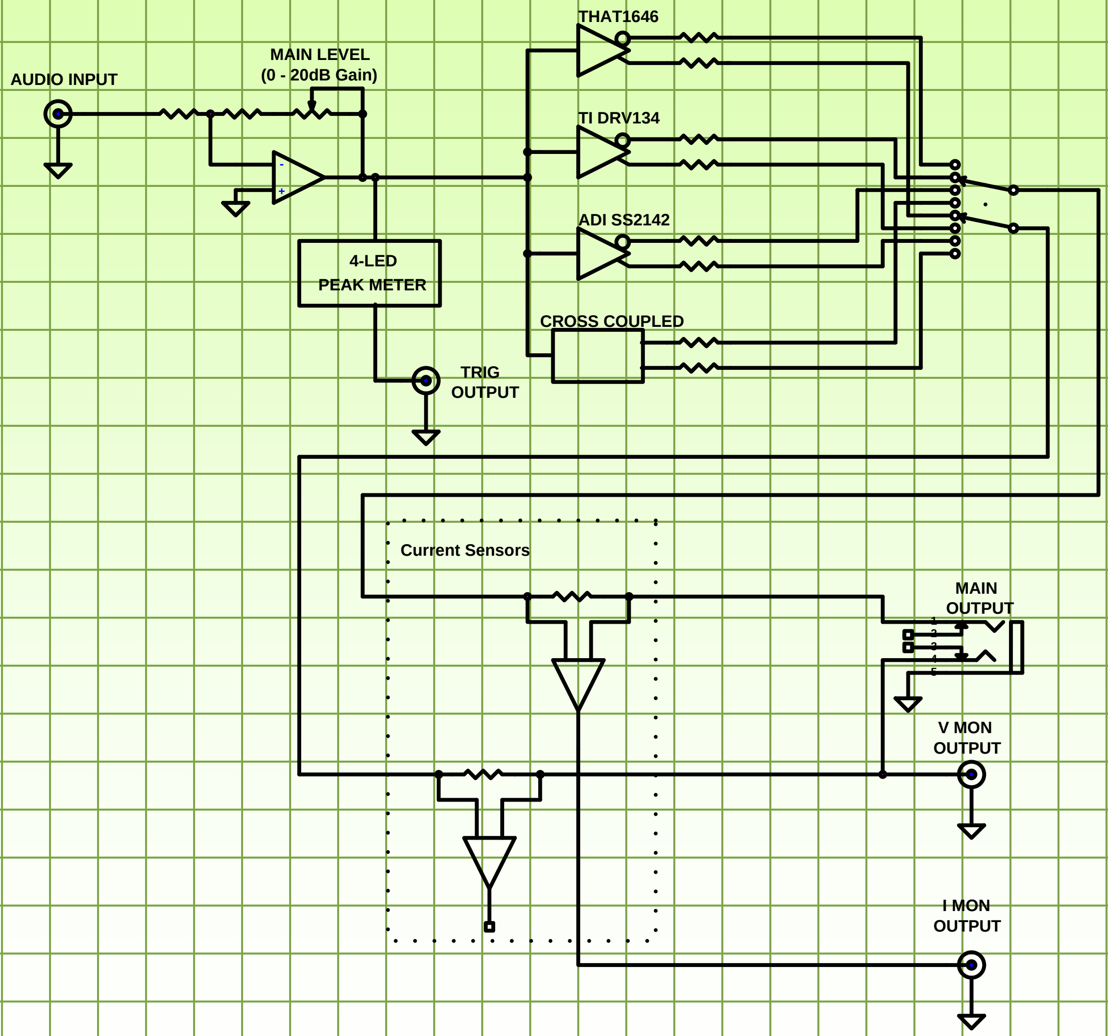
Balanced Floating Output Drivers

- Imitate some aspects of output transformers
- High common-mode output impedance (several kΩ)
- Low differential output impedance
- Feedback minimizes common-mode output current (Iout+ = -Iout-)
- Output appears across two output terminals
  - Whether or not one is grounded

Clipping Behavior

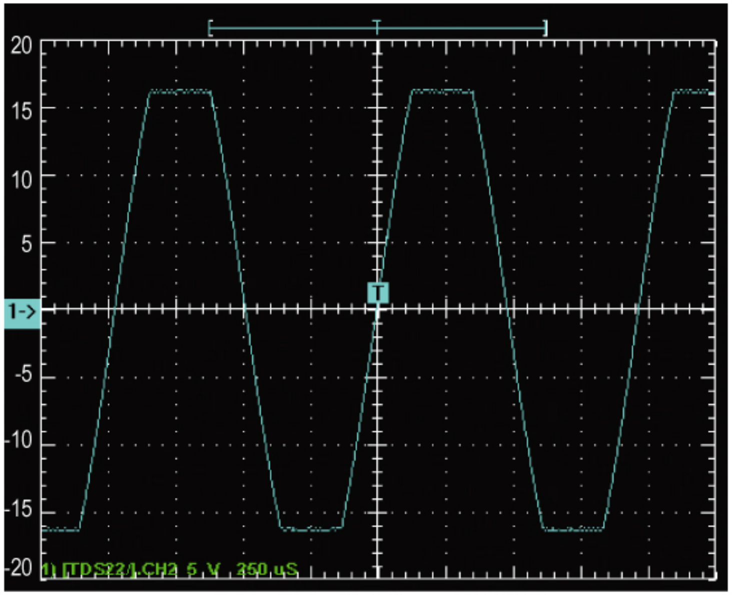
- Traditional designs can lose control over output current if clipped when one output is grounded
  - CM feedback is lost
  - Output current in grounded leg increases to current limit
  - Can lead to distorted crosstalk
- Outsmarts® CM feedback loop maintains control
  - No current limiting
  - Less sensitive PCB layouts

OutSmarts Demo Board - Block Diagram

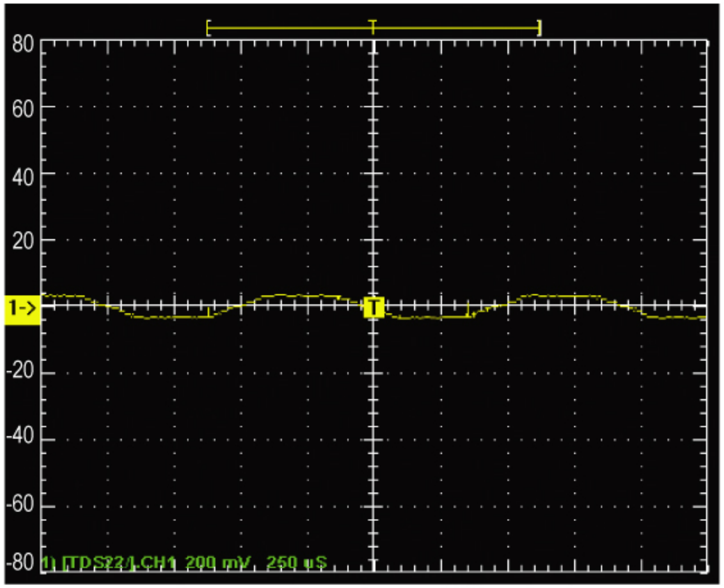


Clipping Into Single-ended Loads

- THAT 1606/1646 Behavior



Active Output Voltage (5 V/DIV)

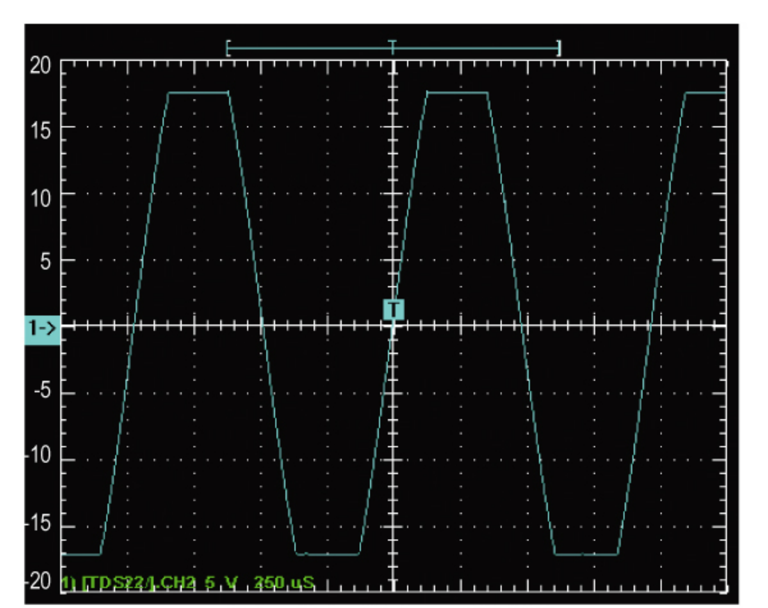


Grounded Output Current (20 mA/DIV)

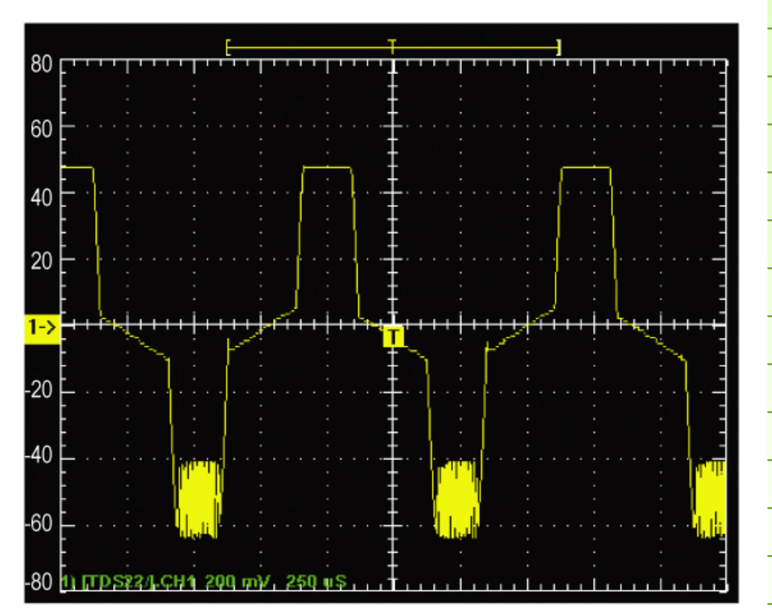
Note: f_{IN} = 1 kHz, $Z_{LOAD(+)}$ = 10 kΩ, $Z_{LOAD(-)}$ = 0 Ω

Clipping Into Single-ended Loads

- SSM2142 Misbehavior



Active Output Voltage (5 V/DIV)

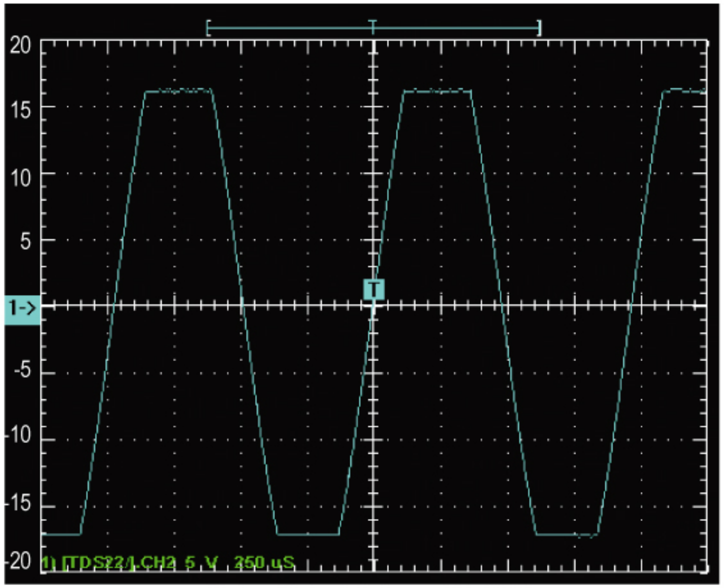


Grounded Output Current (20 mA/DIV)

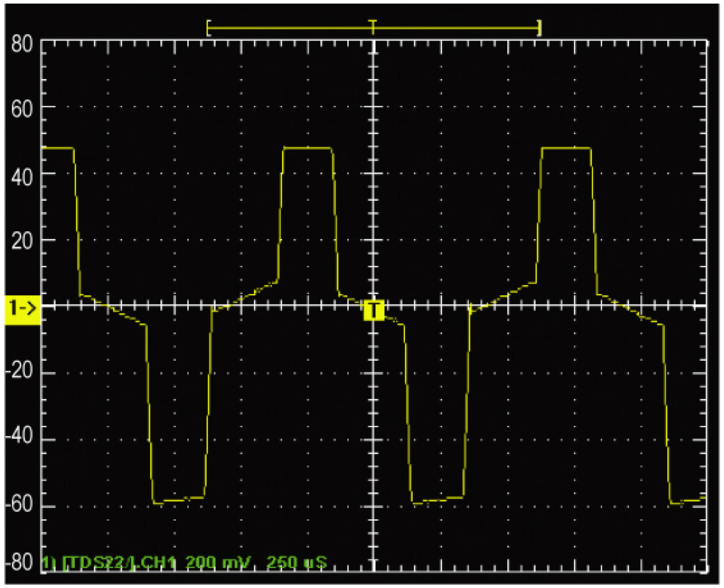
Note: f_{IN} = 1 kHz, $Z_{LOAD(+)}$ = 10 kΩ, $Z_{LOAD(-)}$ = 0 Ω

Clipping Into Single-ended Loads

- DRV134/135 Misbehavior



Active Output Voltage (5 V/DIV)



Grounded Output Current (20 mA/DIV)

Note: f_{IN} = 1 kHz, $Z_{LOAD(+)}$ = 10 kΩ, $Z_{LOAD(-)}$ = 0 Ω

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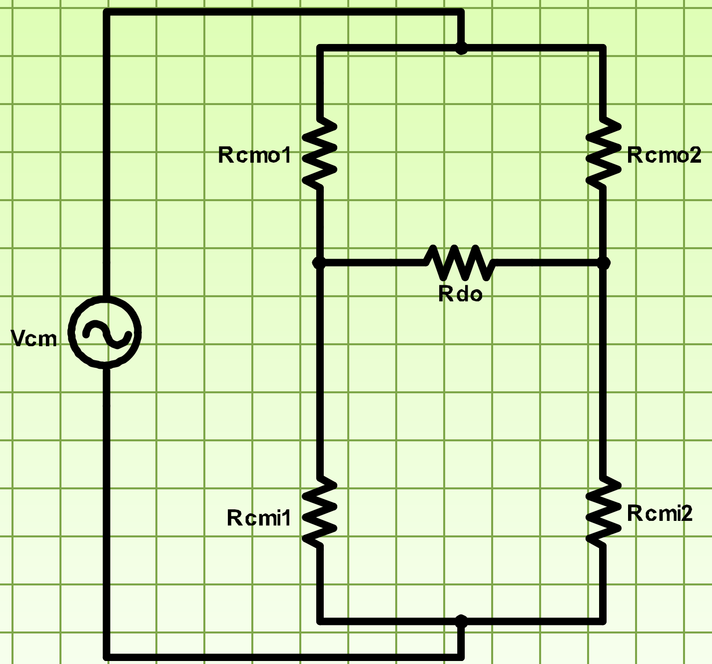
CMRR Depends on Impedance Ratios

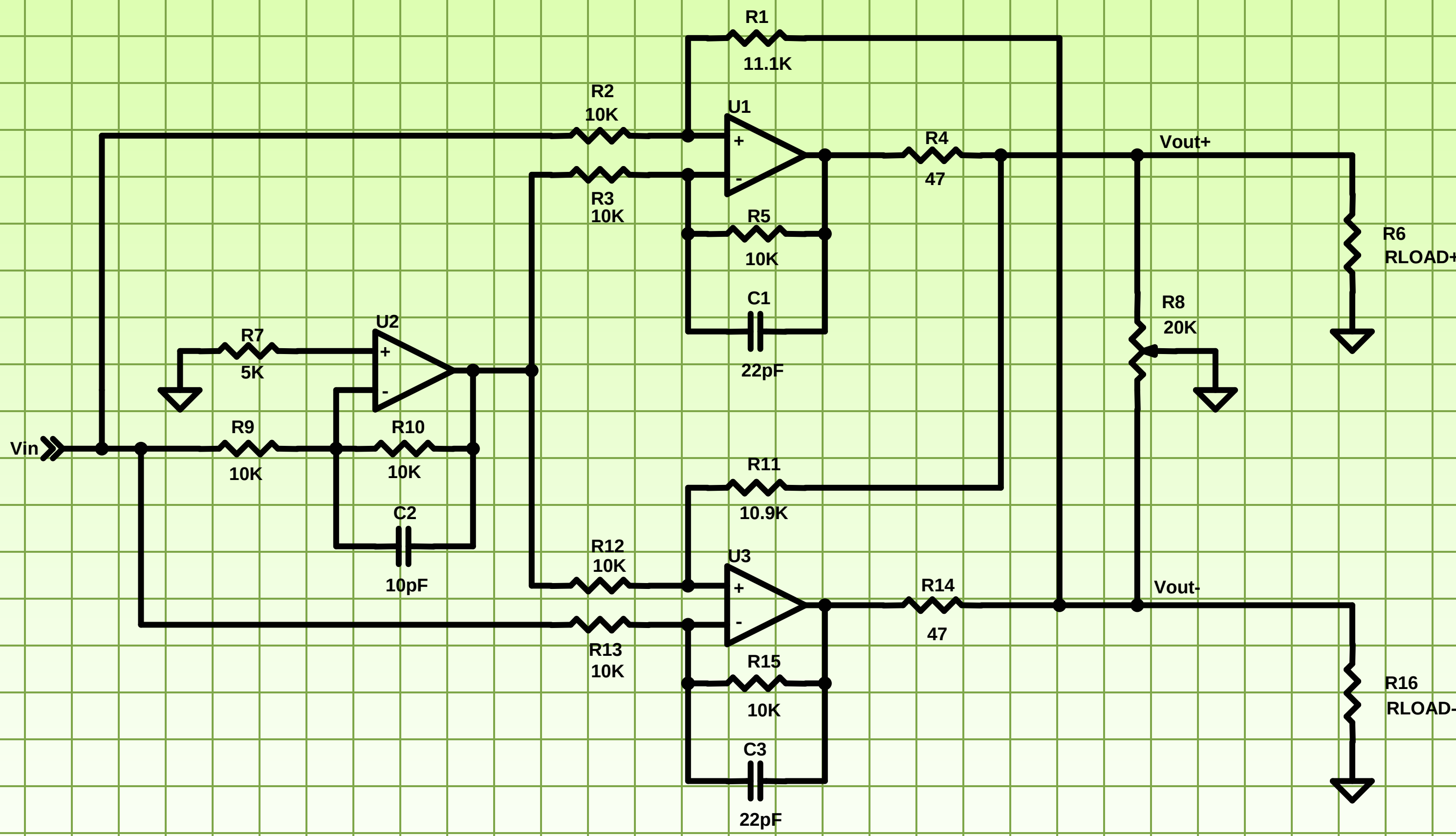


- Wheatstone Bridge
  - Models Balanced Driver/Receiver
- CMRR is high if ratios match
- CMRR degrades if Rcmo1/Rcmo2 ≠ Rcmo1/Rcmo2
- CMRR is unaffected by differential signal level

Signal Balance

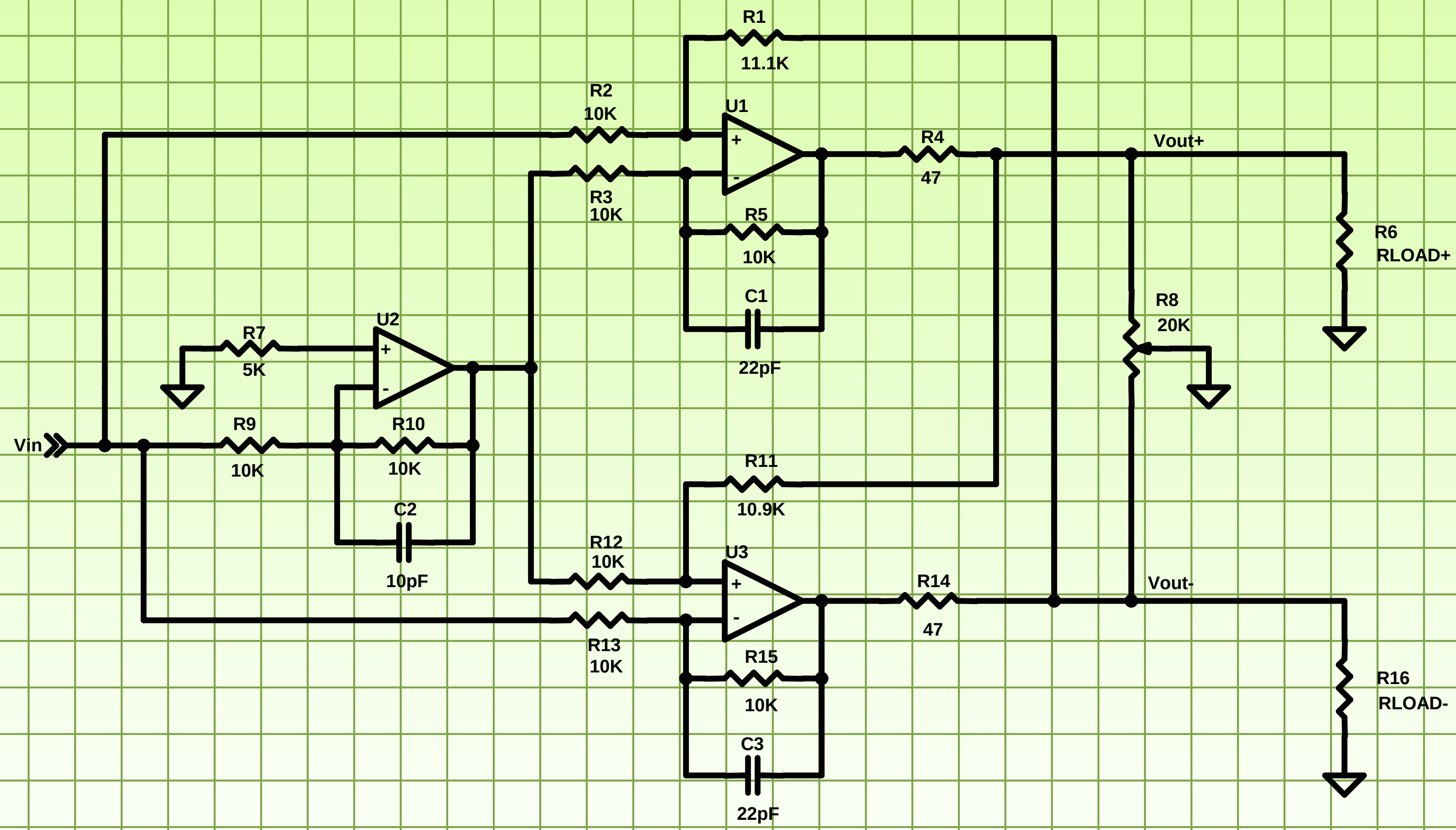
- Signal Balance measures match of + and - output levels
  - Using a perfectly balanced load
- Signal Balance affects only headroom
- Might affect crosstalk in multipair cables
- Does ***not*** affect CMRR

Discrete Balanced Floating Output Driver



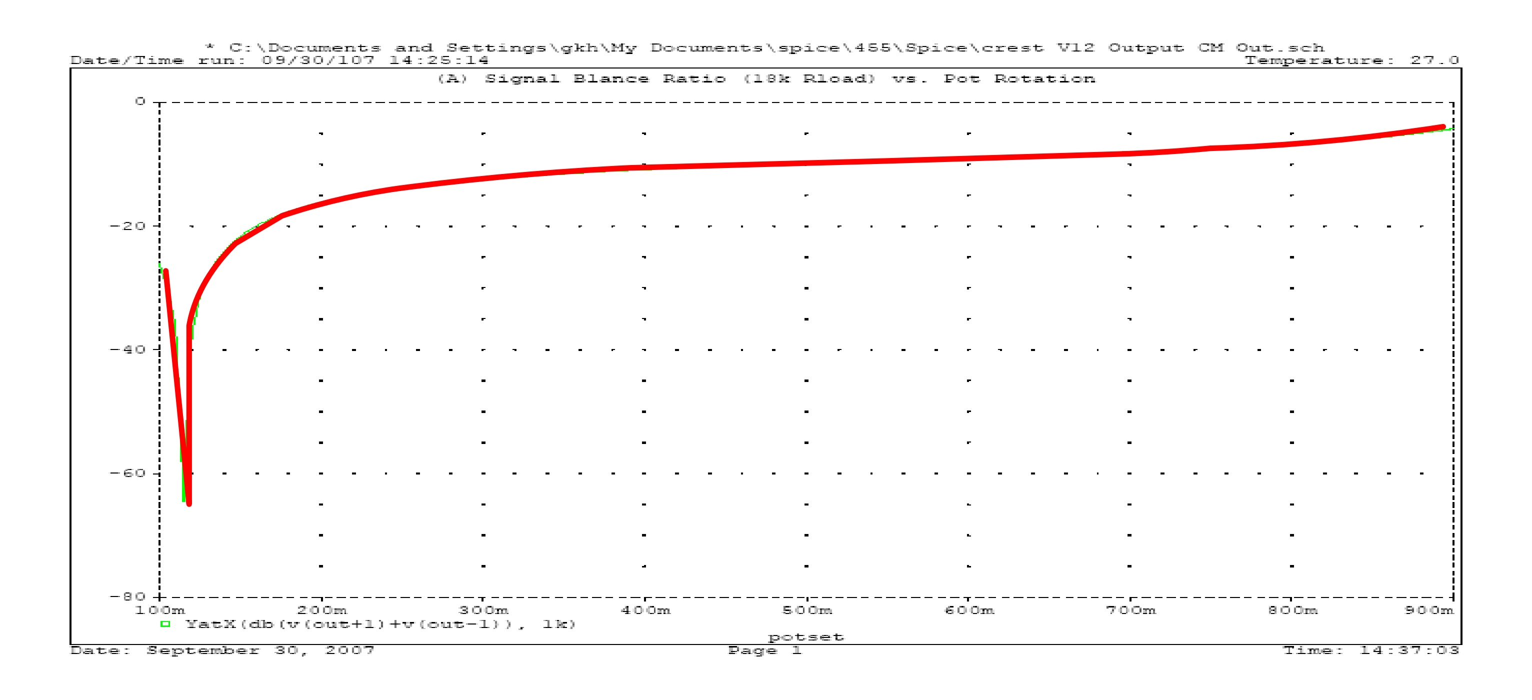
- R1, R11 deliberately increased (nominal 11kΩ)
  - Ensures stability
  - Lowers CM output impedance

Discrete Balanced Floating Output Driver



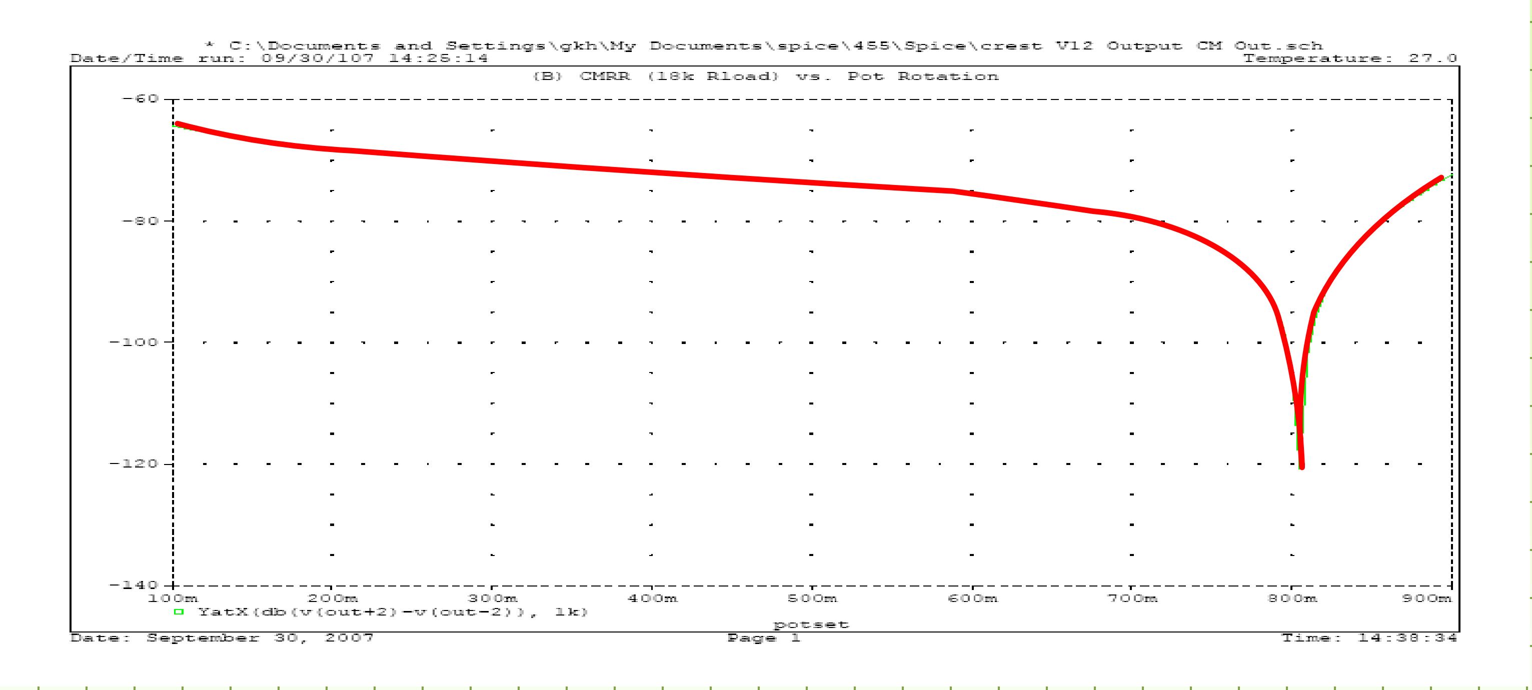
- R8 is typically trimmed for best signal balance
  - Compensates for resistor mismatches (e.g., R1/R11)
  - But this is not the best solution

Signal Balance vs. Pot Rotation



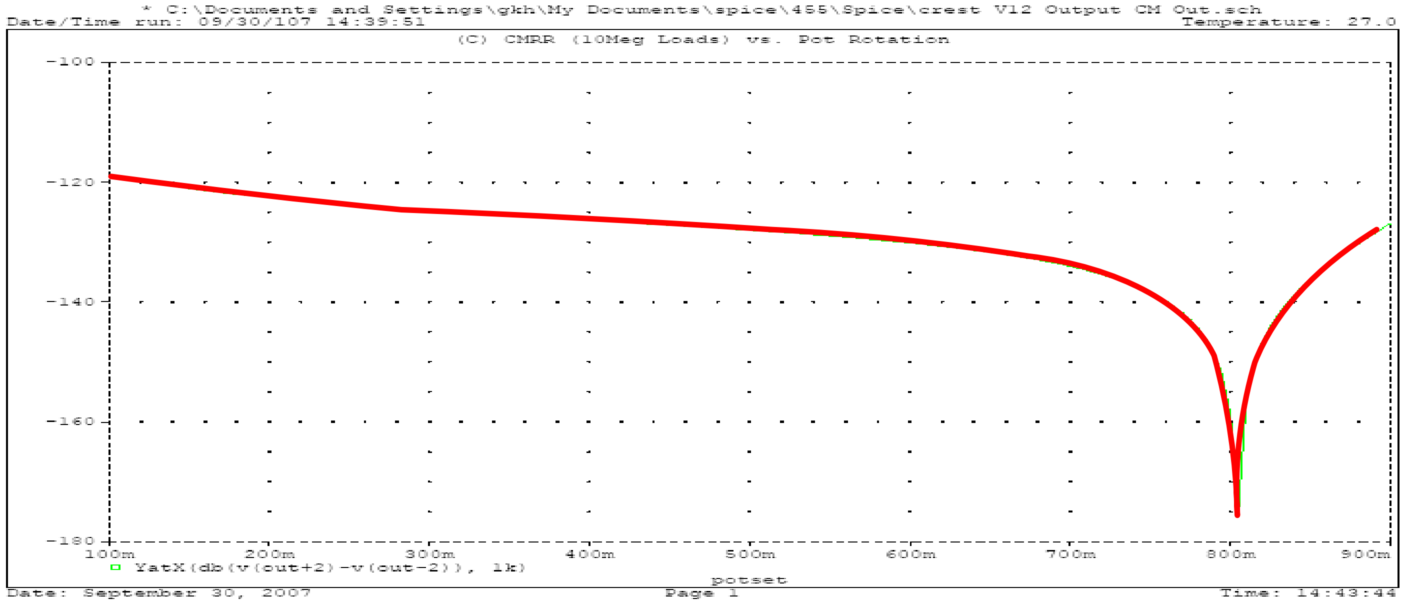
- SBR = 20log((Vo+ + Vo-)/Vin)
- Load is 18 kΩ per output
- Null occurs at about 11.5% pot rotation

CMRR vs. Pot Rotation



- Same 18 kΩ loads (perfectly matched)
- CMRR null occurs at about 80% pot rotation
- CMRR after trim is 10 dB worse than no trim at all

CMRR vs. Pot Rotation – 10 MegΩ Zin



- CMRR vs. Pot Rotation with 10 MegΩ CM loads
- With InGenius input this isn't an issue

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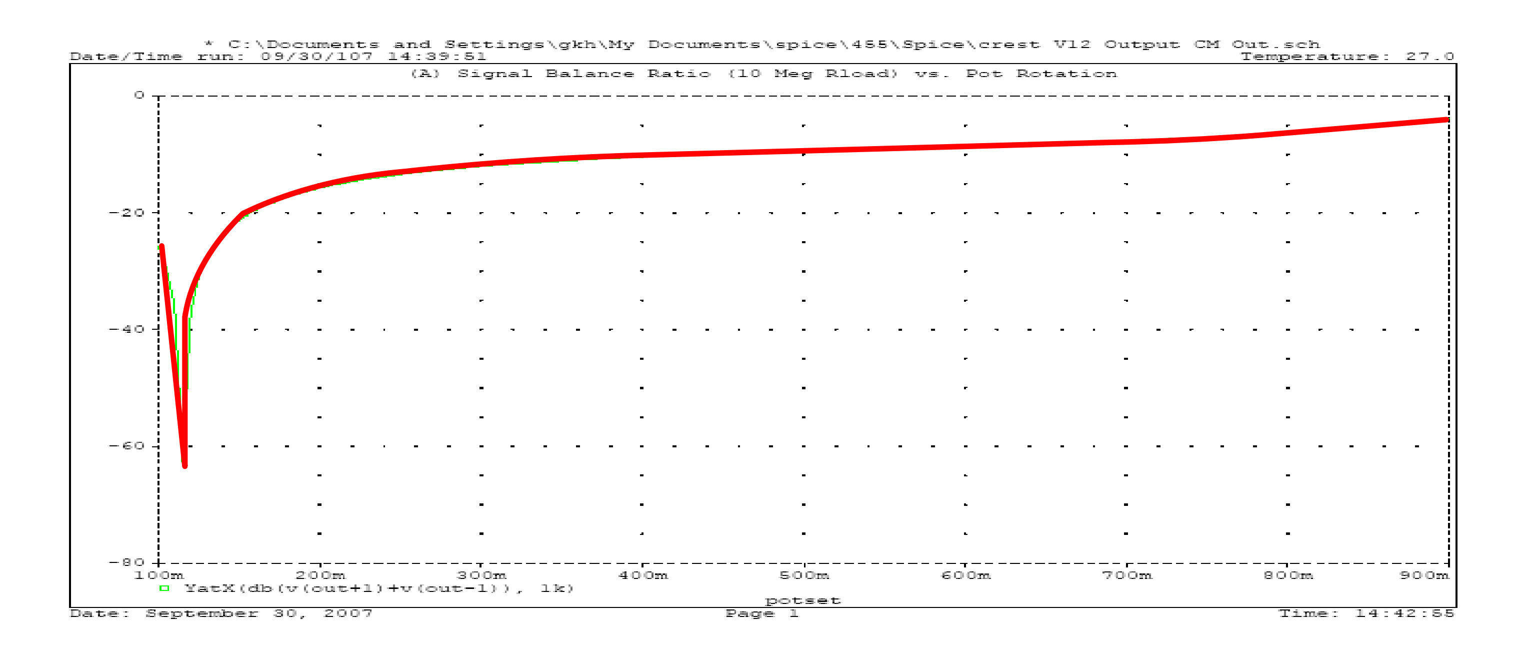
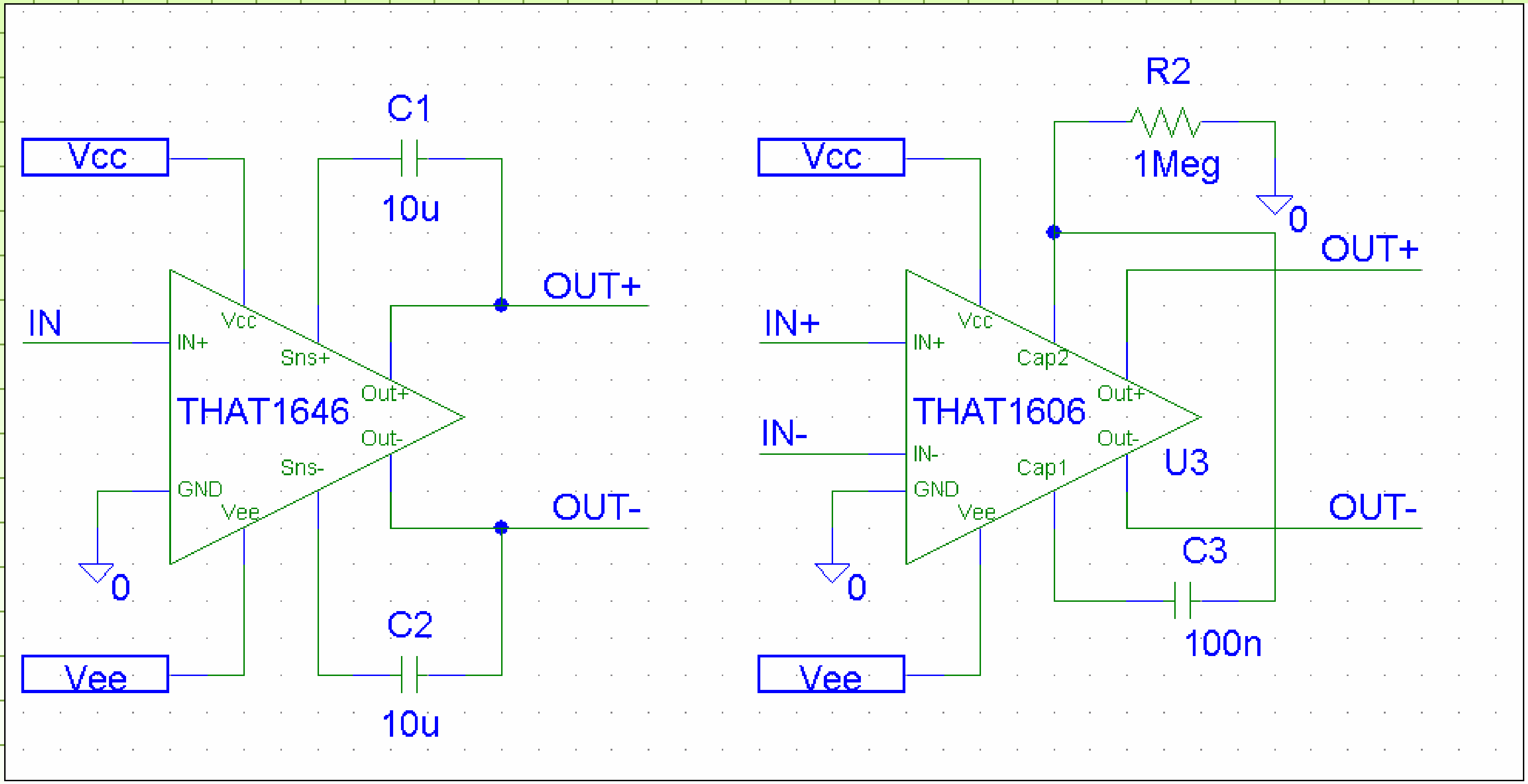
Signal Balance vs. Pot Rotation – 10 MΩ Zin



- However, Signal Balance is unchanged with 10 MegΩ loads

THAT Output Driver ICs



- Trimming is complex – let us do it for you
- 1646/06 include all required trims & adjustments

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Chapter **Wrap Up**

Name Bob Moses

Address 123rd AES Convention
New York, October 2007

Conclusions

- Secret #1: new ICs from THAT!
- Secret #2: Mic Preamps need dc stability
  - Use capacitor in series with Rg
  - Output servo is of limited benefit
  - Input servo can work well, but is expensive
- Secret #3: For digital control, put analog switches inside split pairs of Rg
- Secret #4: Match stray loading on Rg pins
- Secret #5: Log math is easy and fun!
- Secret #6: Cross-coupled balanced outputs misbehave in some real world conditions
- Secret #7: OutSmarts® delivers optimal performance under tortuous conditions