Monolithic 4-20 mA Isolating Current Replicator Using GMR Resistors

Wai-Leung Hui[1], William Black[1], Theodore Hermann[2]

[1]Iowa State University

[2]Nonvolatile Electronics, Inc.

Outline

- Review of Isolation Methods
- Description of GMR Isolation Technique
- Characteristics of GMR Resistors
- Detailed Circuit Description
- Experimental Results
- Summary

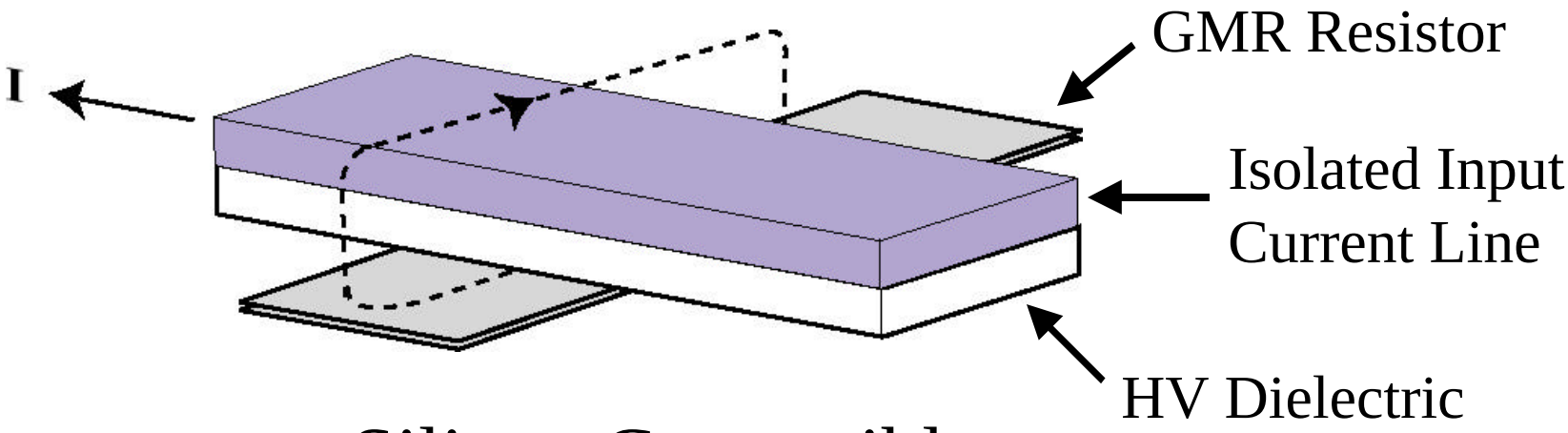
Applications of Isolation Devices

- Long Distance Wired Communications
  - Analog
    - 4-20mA Current Loop (Instrumentation)
  - Digital
    - 4-20mA Current Loop (‘0’ ≤ 4 mA, ‘1’ ≥ 12 mA)
    - RS-232 C/D, RS-423A, RS-422A, RS-485
    - High Speed Networks (IEEE 802.3, 802.14,1394)
- Power Controllers
- Medical Instrumentation

Conventional Isolation Techniques

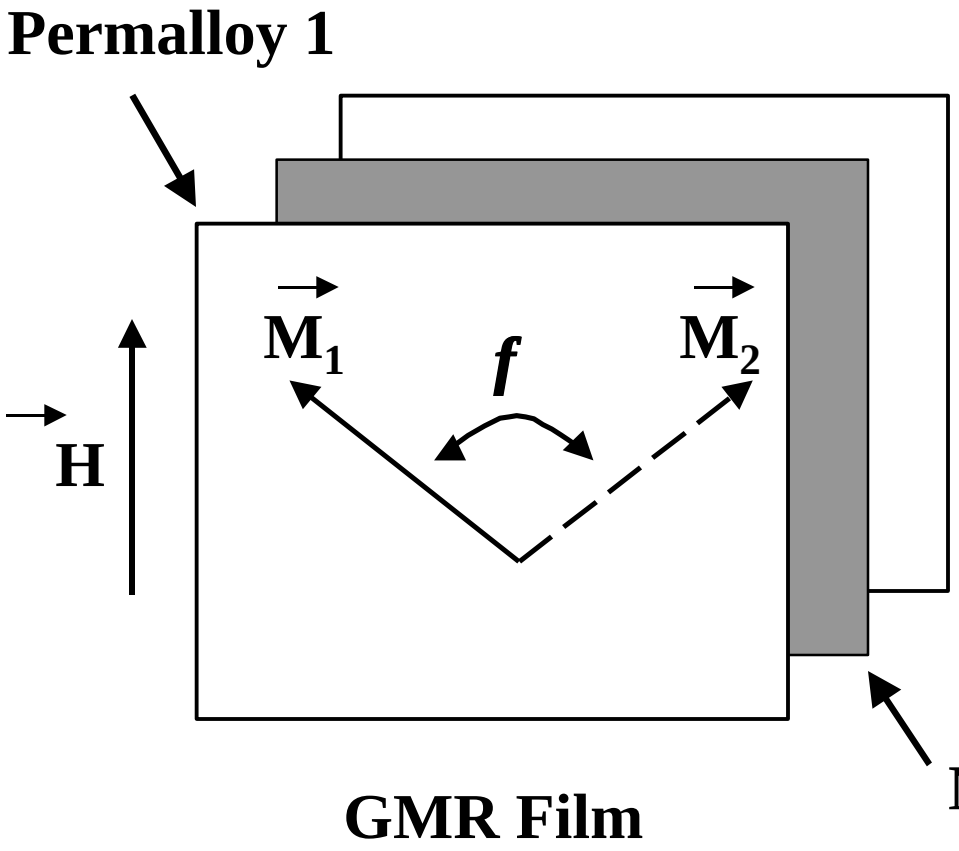
- Optical Isolator
  - Discrete Components
  - Nonlinear
  - Slow
- Transformer or Capacitor Coupling
  - Discrete or Multi-Chip
  - AC Only (modulator/demodulator for DC)

Magnetic Field Sensing Isolation with GMR Resistor



- Silicon Compatible
- High Speed (~1nsec.)
- Good Linearity

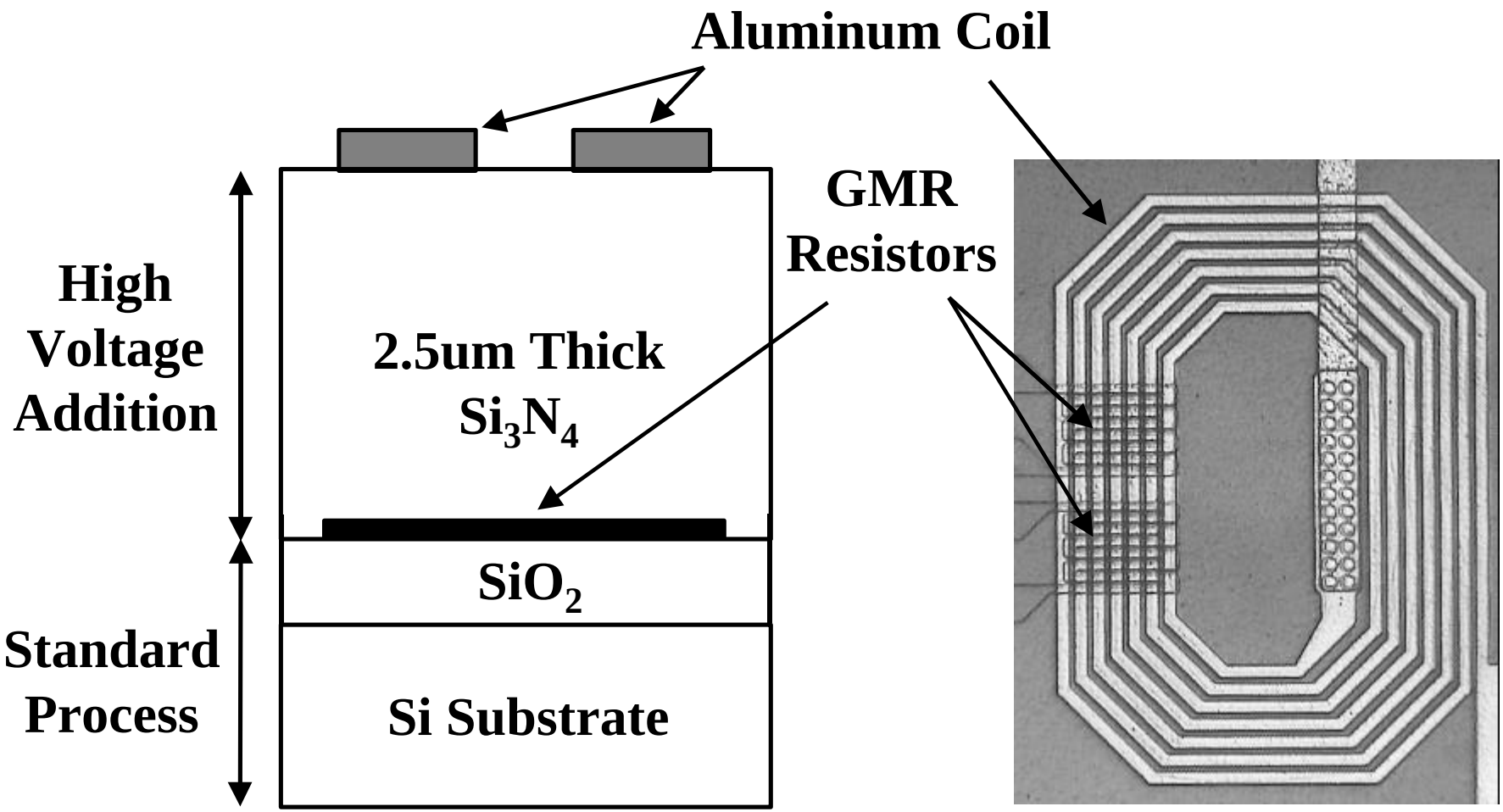
Giant-Magneto-Resistance Effect



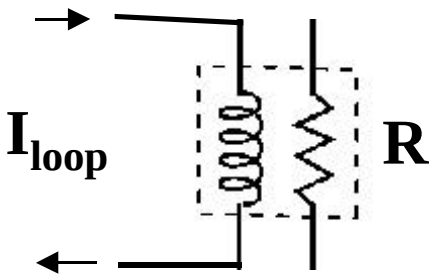
$$\rho \approx \rho_0 - \frac{\Delta\rho_{max}}{2}\cos\phi$$

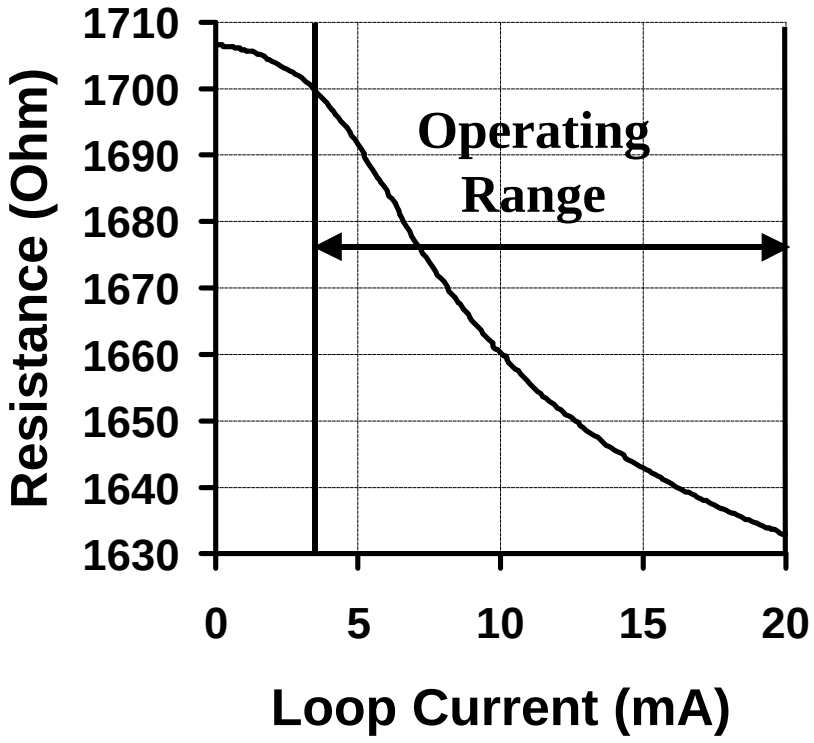
(ϕ is function of applied field)

Isolated Current Loop & GMR Resistors

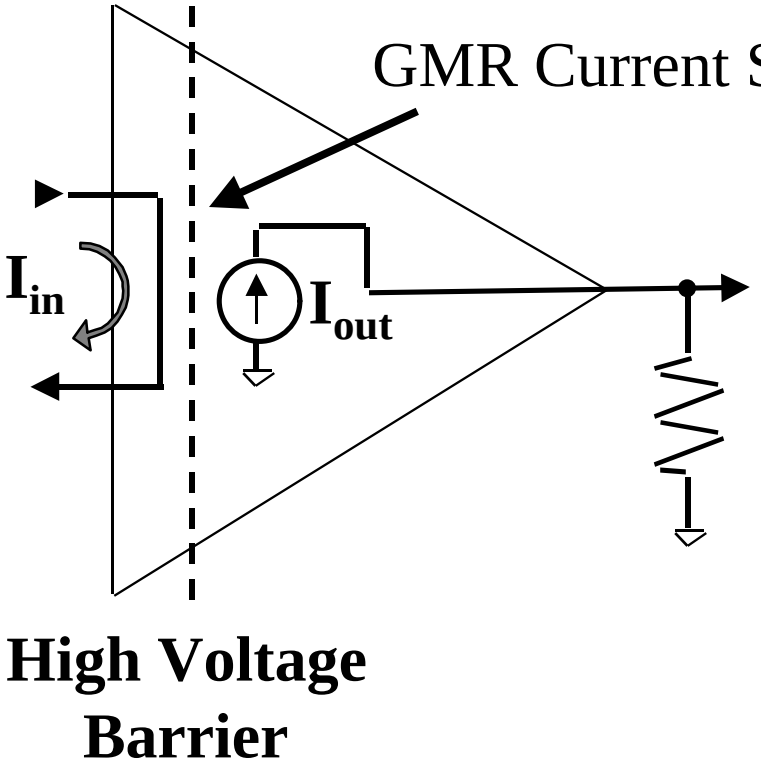


GMR Resistance vs. Isolated Loop Current



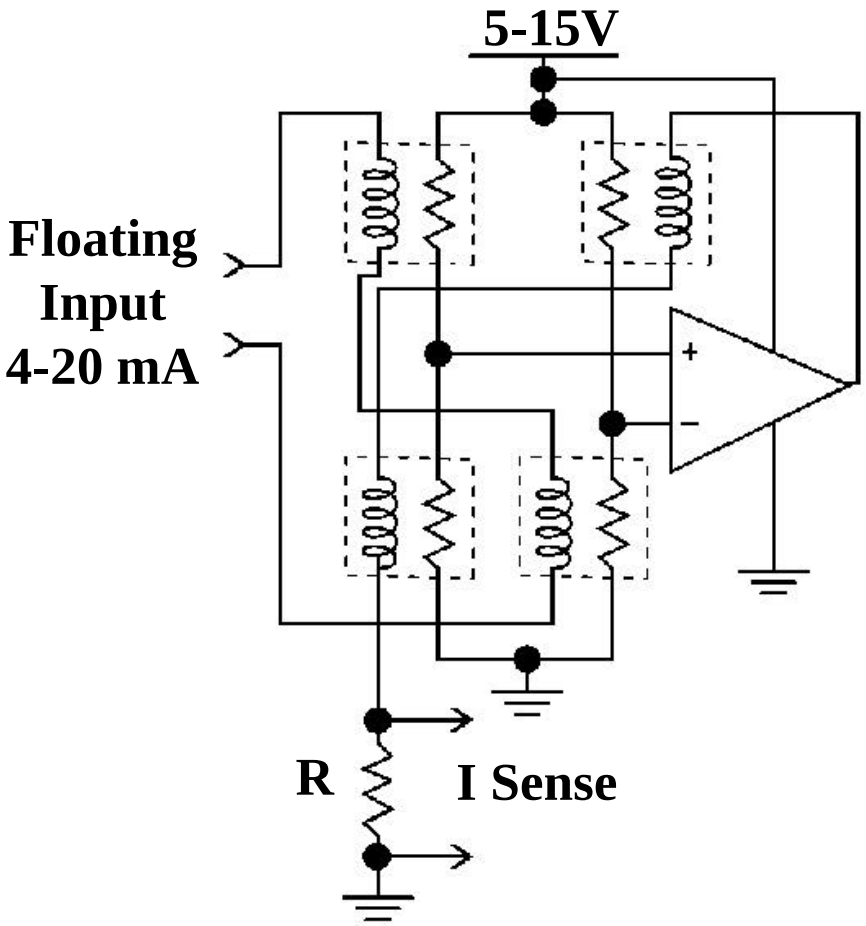


Isolated GMR Current Replicator



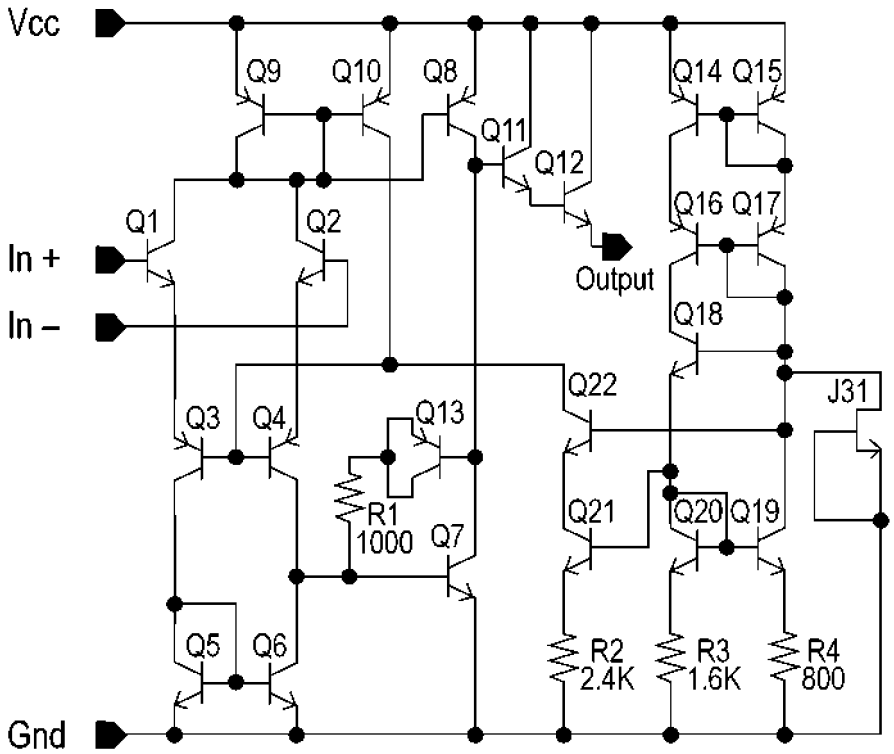
- Typical Applications
  - Isolated 4 - 20 mA Receiver
  - Isolation Amp (with V to I)
  - Opto-isolator Equivalent

Complete Current Replicator



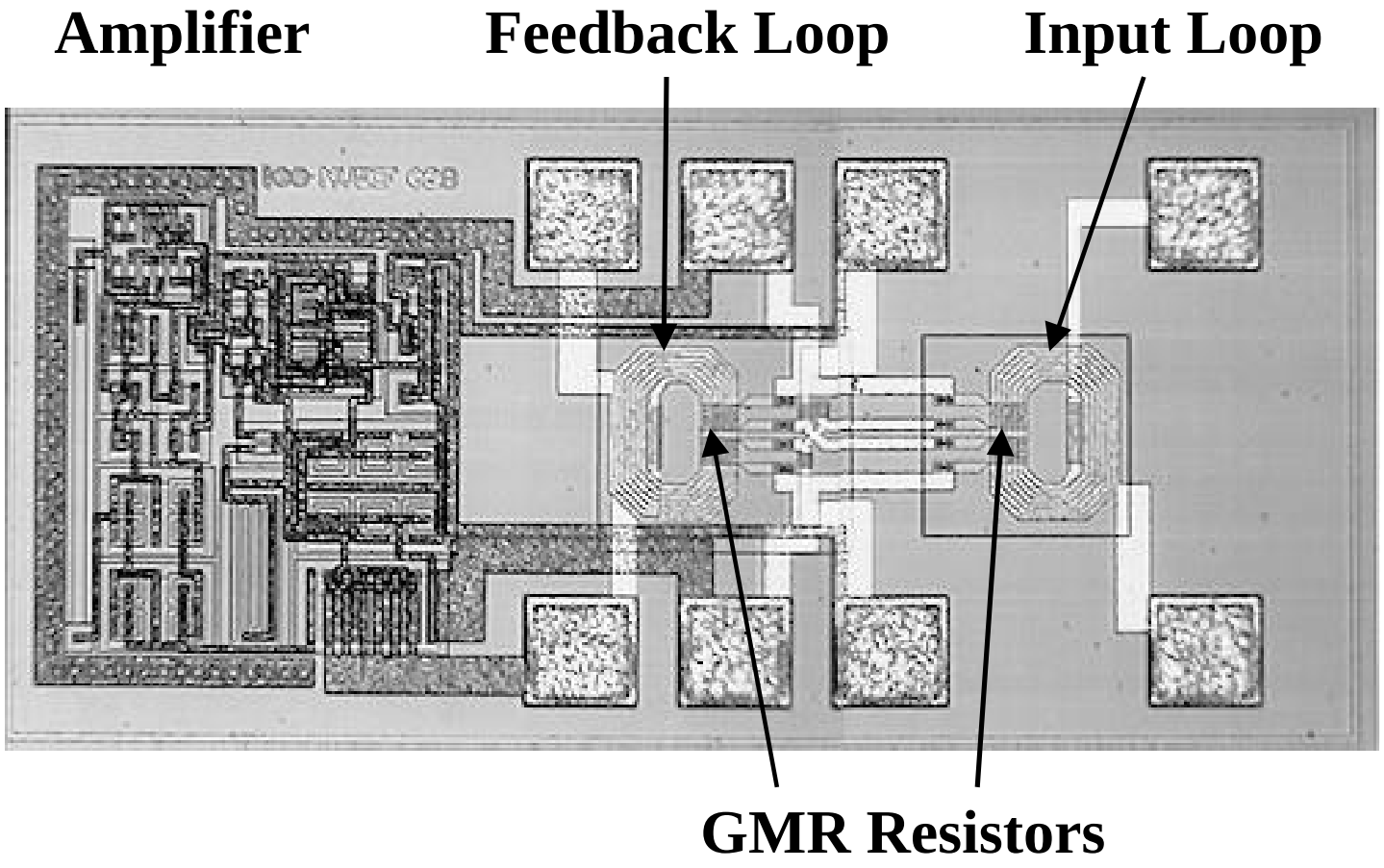
- Amplifier Requirements
  - High Gm
  - Limited CM Range
  - Limited Output Voltage Swing
- GMR Linearity Requirements
  - Reduced by Matching
- Effect of Bridge Offset
  - Input Current Offset
  - Small Nonlinearity

Amplifier Schematic

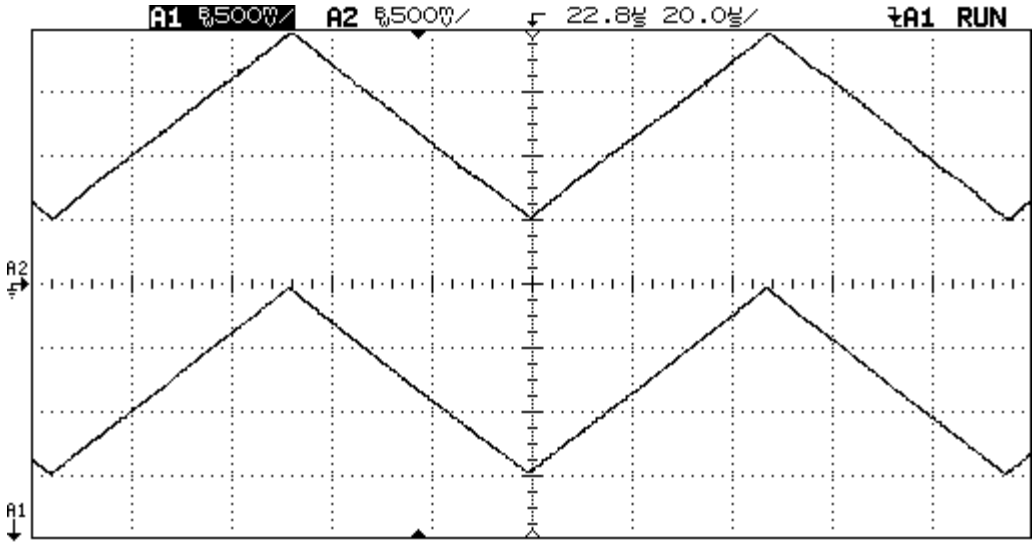


- Standard Bipolar Process
  - 4 μm Minimum Feature
  - 20 V Bv_{ceo}
- Hi Gm (~150 S @10 mA)
- CM Feedback
- Supply Independent Biasing

Die Photo



Current Ramp Response

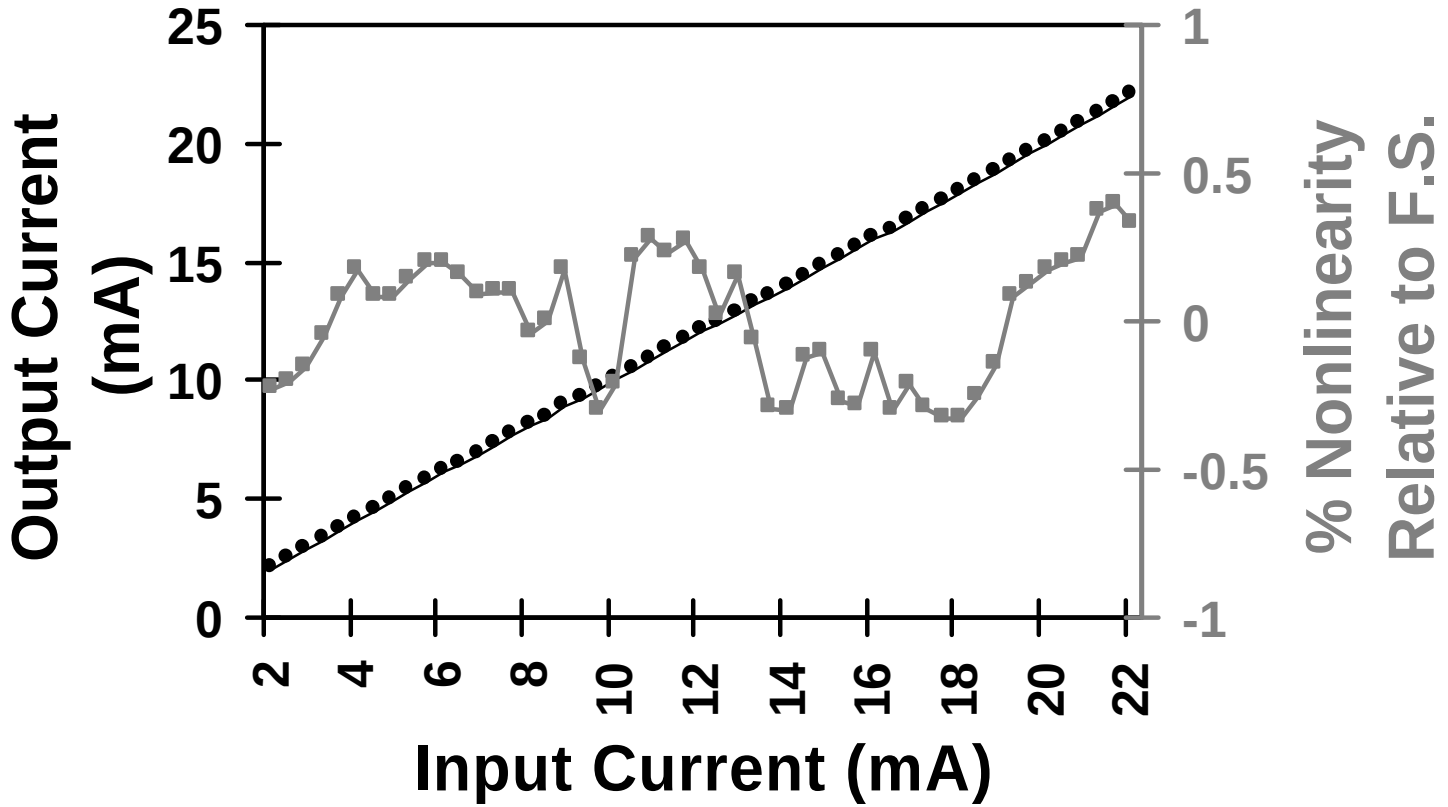


Output:
5 mA/div

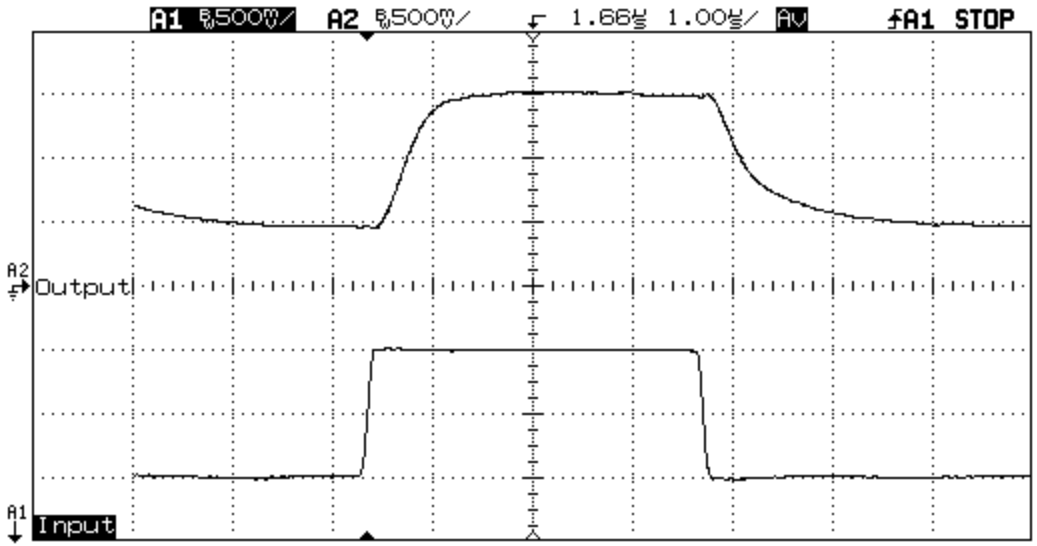
Input:
5 mA/div

20 µs/div

Isolator Transfer Characteristic



Step Response

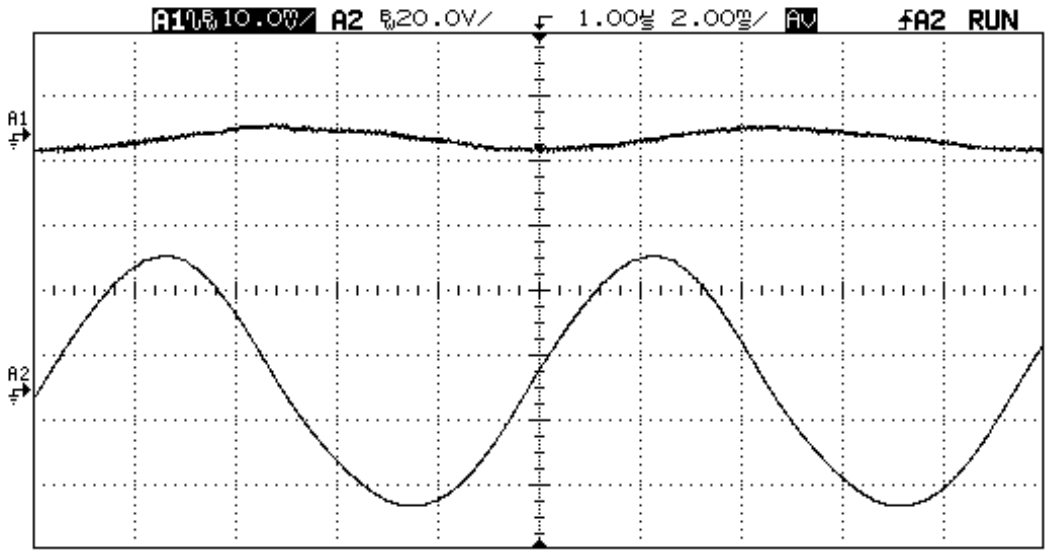


Output:
5 mA/div

Input:
5 mA/div

1 μs/div

CMR Performance
(I_{in} = 10 mA DC)



Output:
100 µA/div

Input:
20 V/div

2 ms/div

Isolator Characteristics Summary

Power Dissipation (Iout = 4 mA)	53	mW
Error from best-fit line after single point offset trim (4-20 mA range)	< .5	% of full scale
Untrimmed Equiv. Offset	5	mA
- 3 dB Bandwidth	DC - 400	kHz
Maximum Slew Rate (100 Ω Load)	20	mA/usec.
± 10 mA Settling Time (.1%)	< 2	μsec.
Equiv. Input & Output Noise	7.4	μA_{rms} (BW =1MHz)
Isolation Voltage (8 pin DIP)	> 1500	Volts
Die Size	.72 x 1.5	mm

Summary

- Monolithic Si Compatible Isolation Method
  - Simple GMR & Si_3N_4 Addition to Standard Process
  - May be Used with Multiple Isolated Inputs
- 4-20 mA Isolating Replicator Demonstrated
  - 4 μm Standard Linear Bipolar Process
  - > 1500 V Isolation (8 pin DIP)

GMR Bridge Characteristics