Low Noise Portable Electroencephalogram (EEG)

Nick Arango

Why an EEG

- Neat Applications
  - sleep analysis
  - medical diagnosis
  - computer human interface
- Hard to measure
  - 1-100μV signals from .1 to 40 Hz
  - very high source impedance

Medical EEG

Medical EEG

Commercial EEG

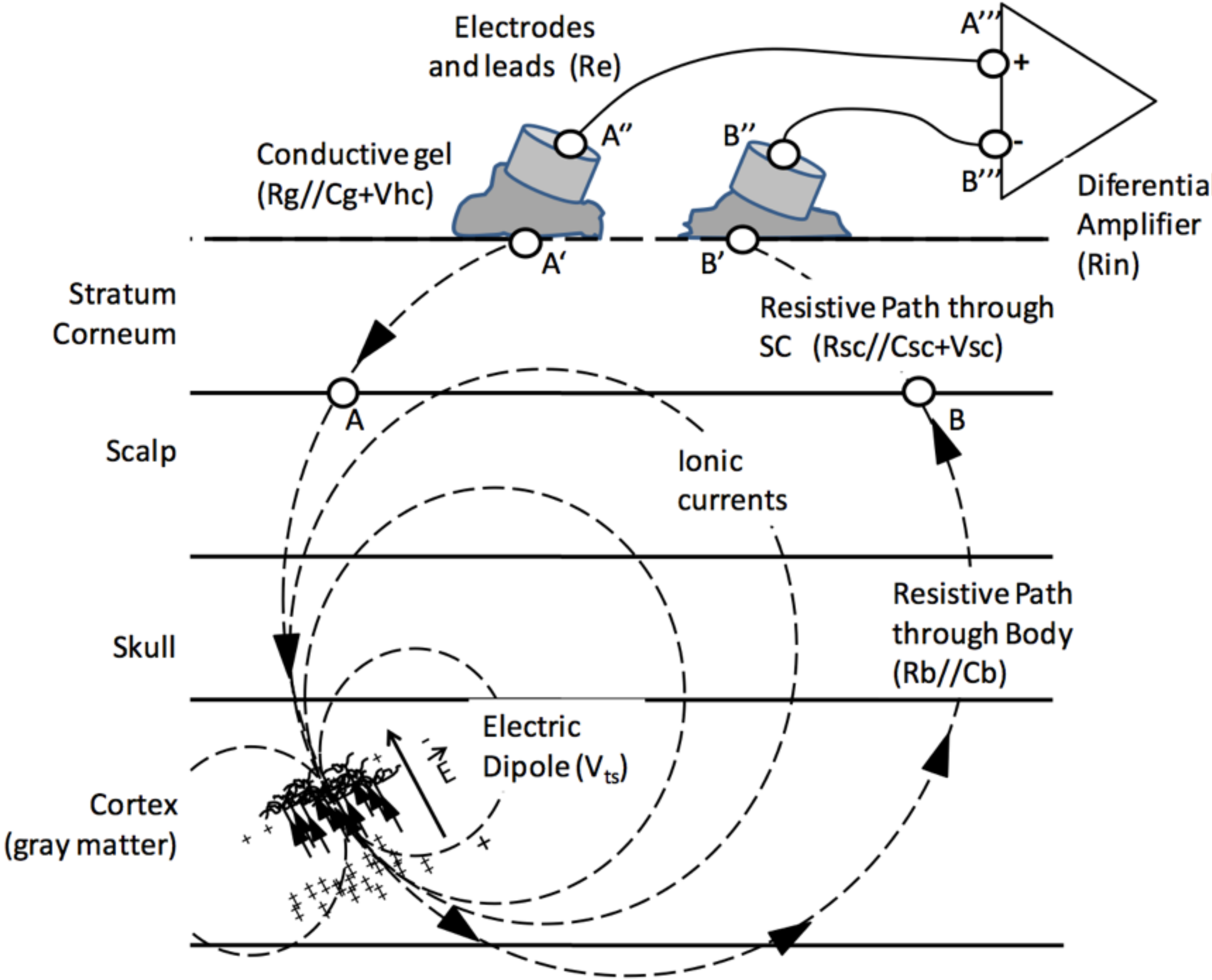
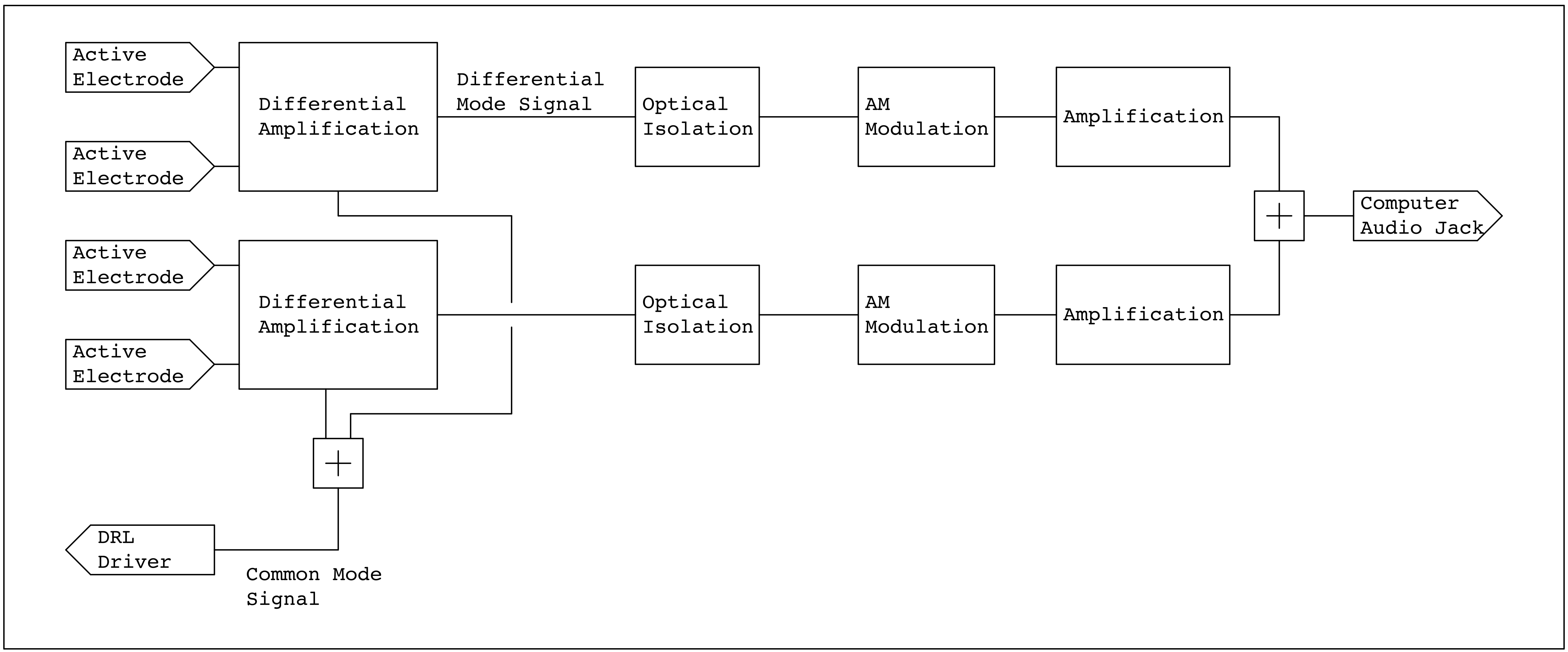


Figure from Dry EEG Electrodes M. A. Lopez-Gordo, D. Sanchez-Morillo, and F. Pelayo Valle

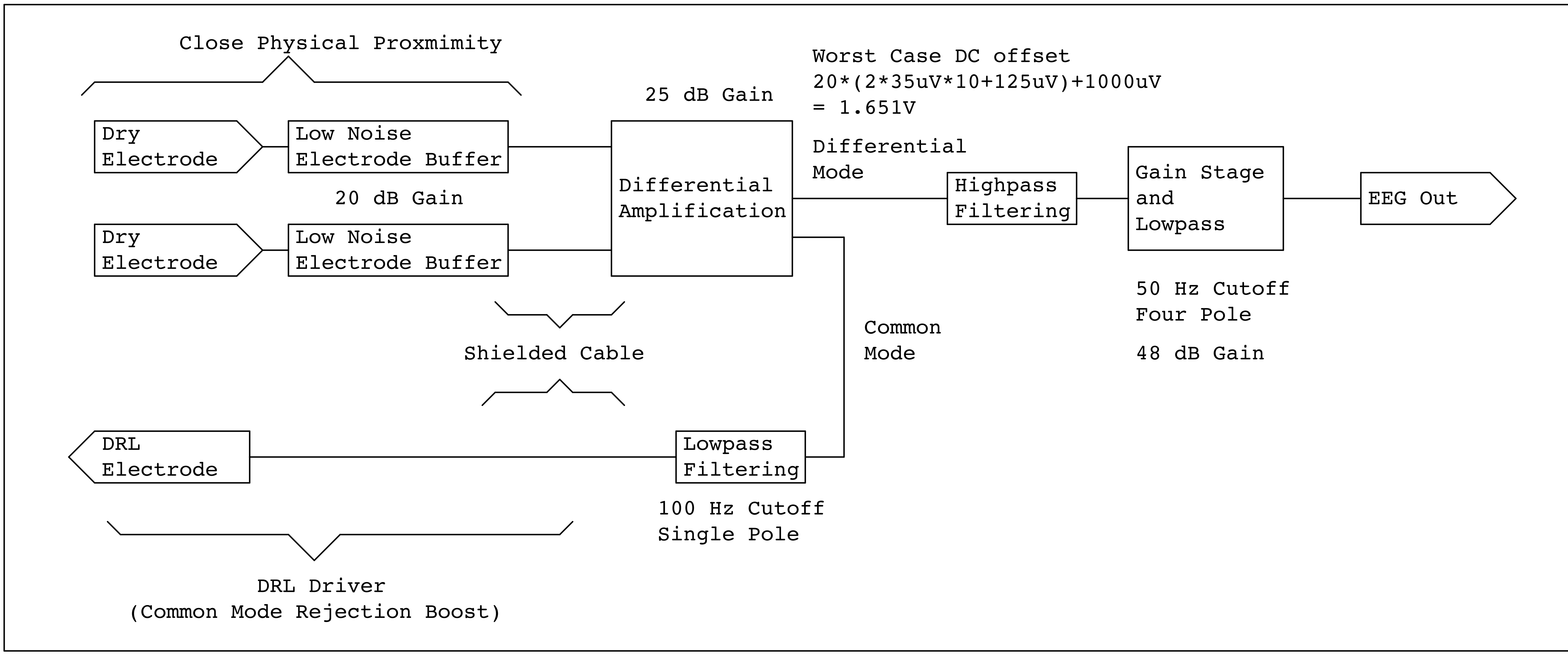
Design Goals

- Battery operated
- Reusable, dry electrodes
- 40dB signal to noise ratio
- Drive a computer

System Overview



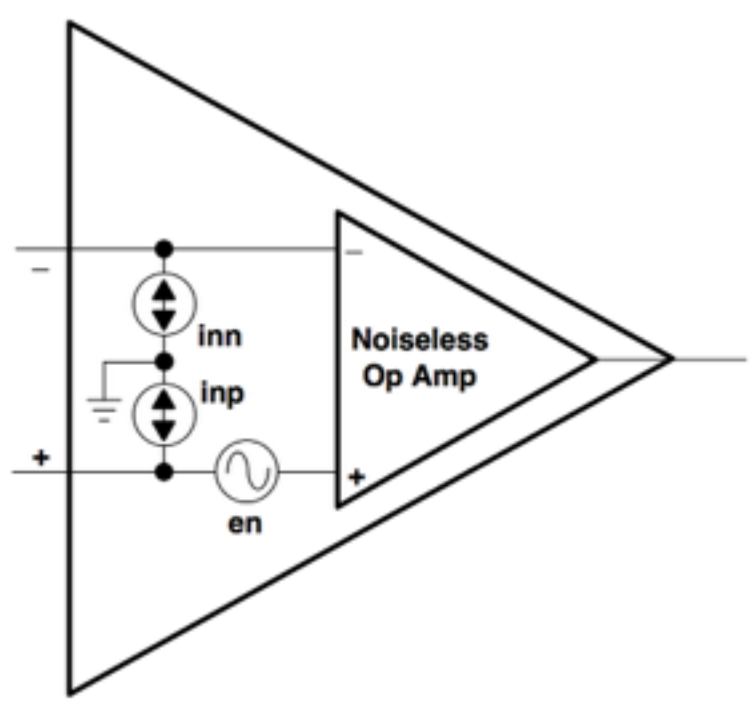
Front End Design



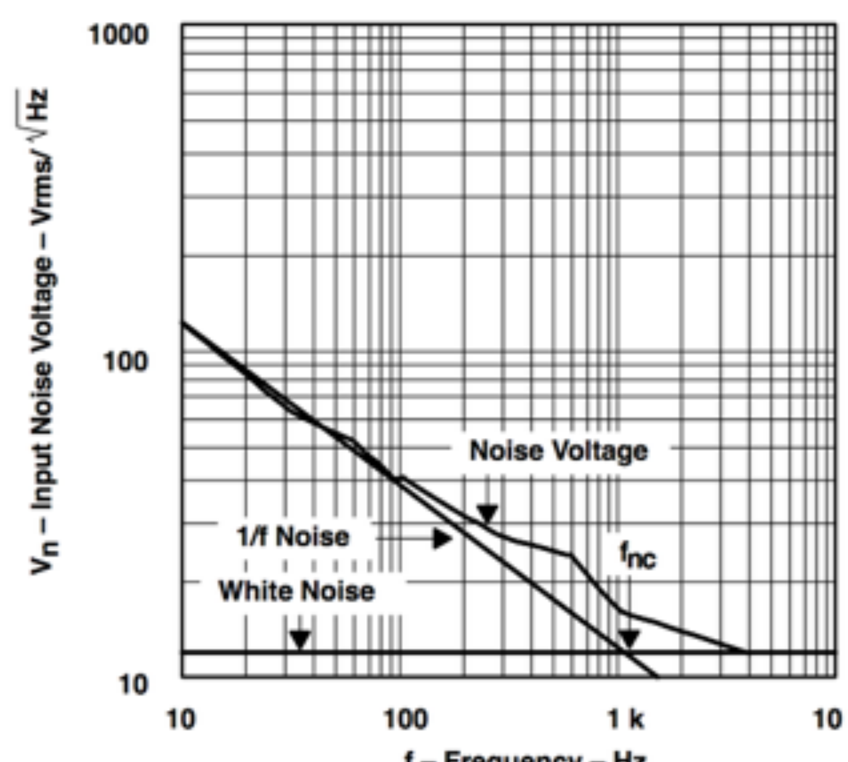
Noise Considerations

- Amplifiers must be selected carefully selected to minimize low frequency noise
- 1/f noise dominates the .1 - 40 Hz range (EEG signal range)
- both voltage and current noise must be considered

opamp noise model



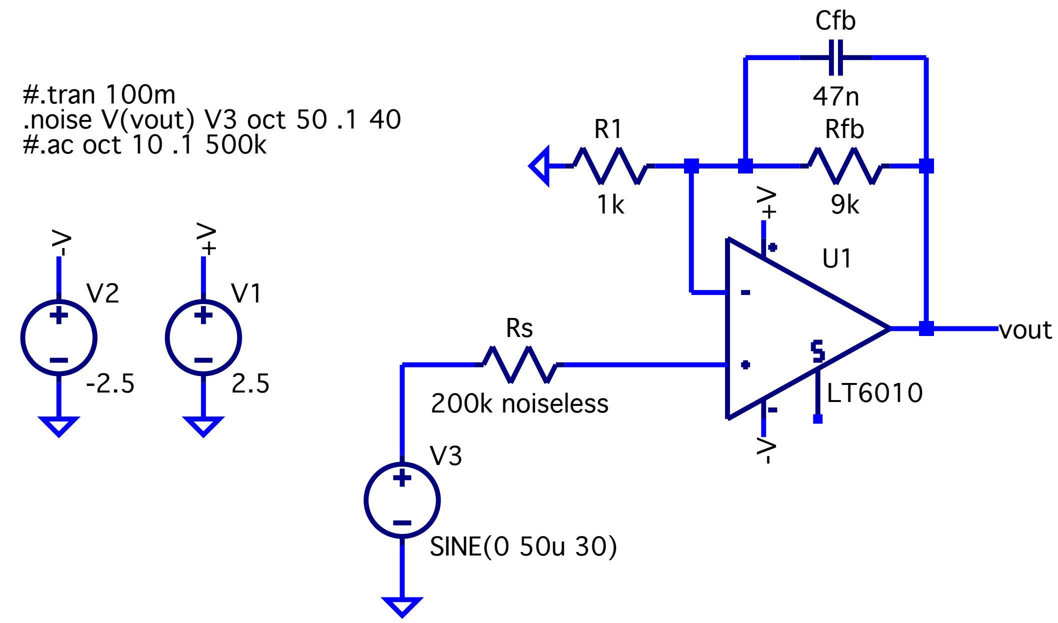
opamp voltage noise characteristics

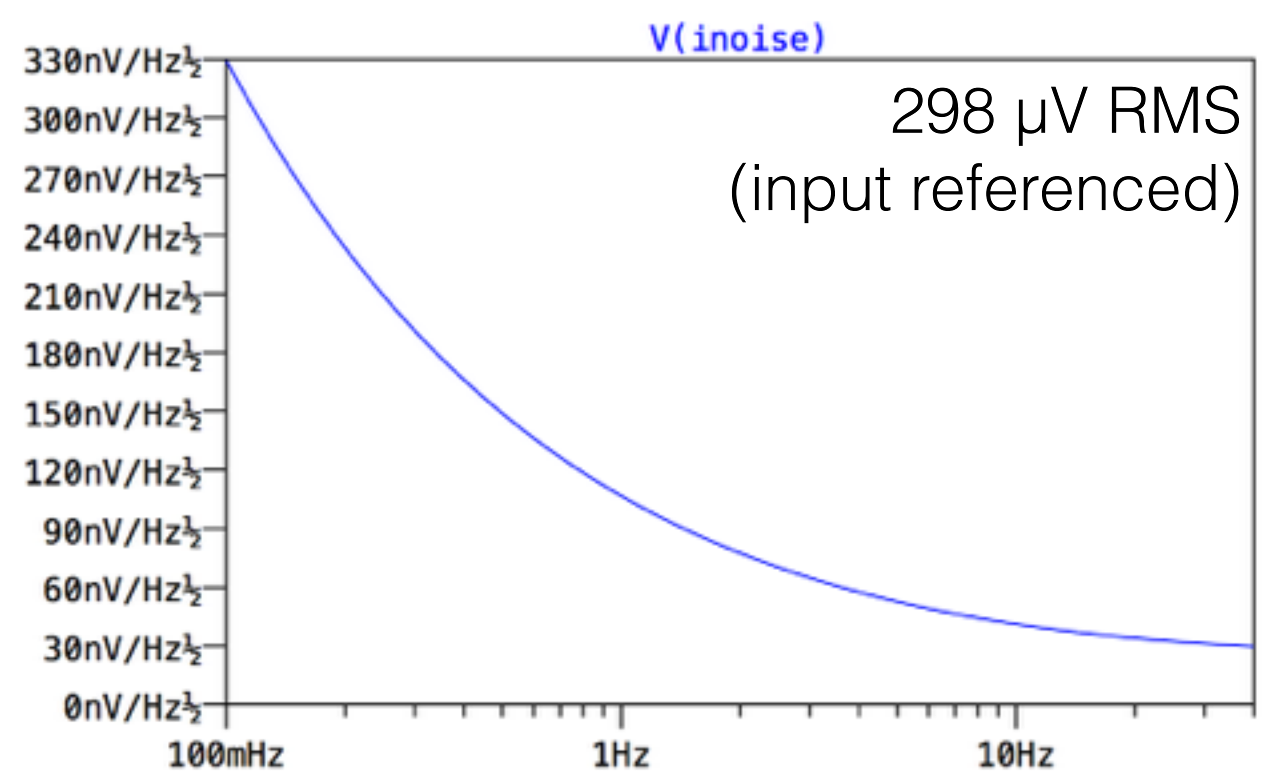


figures from TI's *Op Amps for Everyone* whitepaper

SPICE Noise Simulation

- frontend noise is the most critical in the system
- must be less than 1μV RMS input referenced to hit 40dB SNR target
- low input offset current and voltage needed
- LT6010 selected





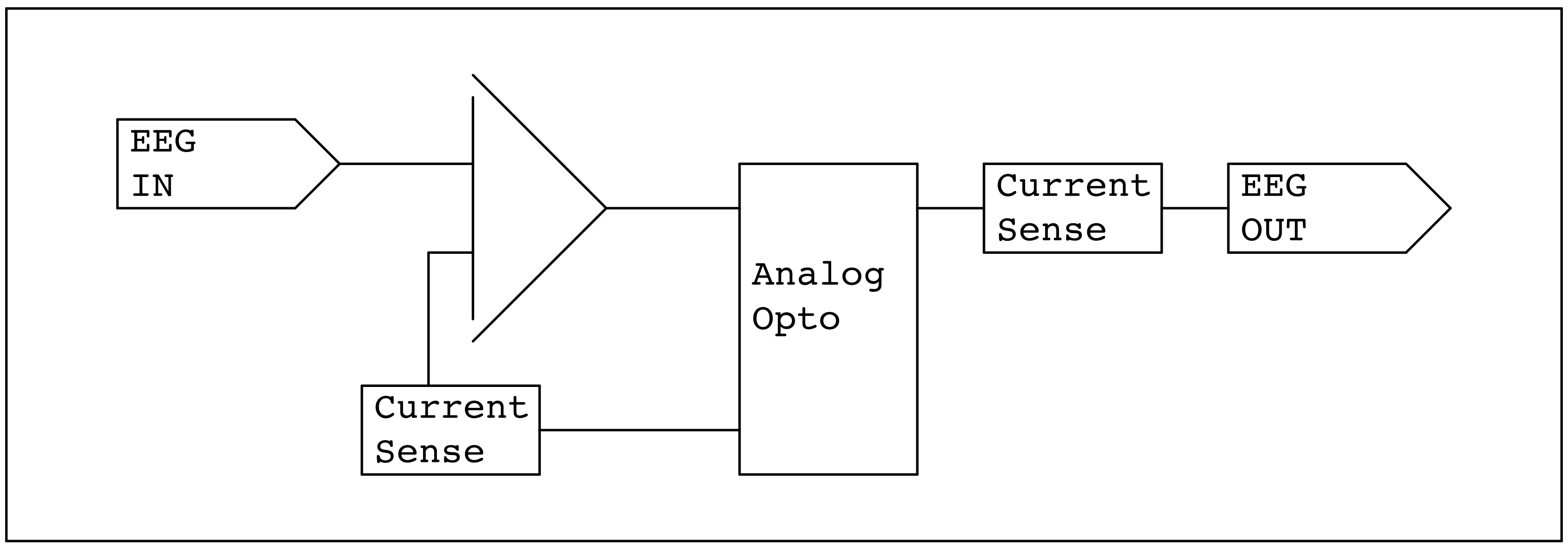
Differential Amplifier

- Signal on the order of 100-1000uV
- 60dB SNR with jellybean instrumentation amp
- Common mode feedback boosts CMMRR

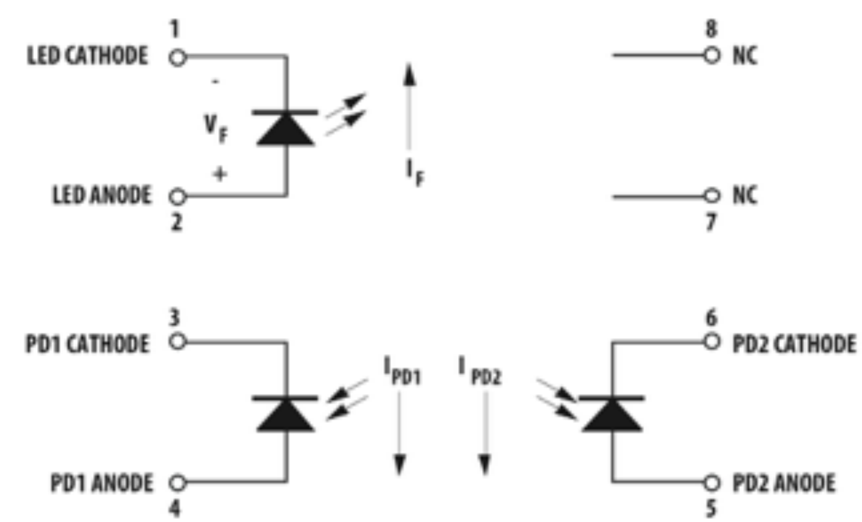
AD620

Parameter	Conditions	AD620A			AD620B			AD620S[1]			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Common-Mode Rejection											
Ratio DC to 60 Hz with											
1 kΩ Source Imbalance	V_{CM} = 0 V to ± 10 V										
G = 1		73	90		80	90		73	90		dB
G = 10		93	110		100	110		93	110		dB
G = 100		110	130		120	130		110	130		dB
G = 1000		110	130		120	130		110	130		dB
OUTPUT											
Output Swing	R_L = 10 kΩ										
	V_S = ±2.3 V to ± 5 V	$-V_S$ + 1.1		$+V_S$ − 1.2	$-V_S$ + 1.1		$+V_S$ − 1.2	$-V_S$ + 1.1		$+V_S$ − 1.2	V
Overtemperature		$-V_S$ + 1.4		$+V_S$ − 1.3	$-V_S$ + 1.4		$+V_S$ − 1.3	$-V_S$ + 1.6		$+V_S$ − 1.3	V
	V_S = ±5 V to ± 18 V	$-V_S$ + 1.2		$+V_S$ − 1.4	$-V_S$ + 1.2		$+V_S$ − 1.4	$-V_S$ + 1.2		$+V_S$ − 1.4	V
Overtemperature		$-V_S$ + 1.6		$+V_S$ − 1.5	$-V_S$ + 1.6		$+V_S$ − 1.5	$-V_S$ + 2.3		$+V_S$ − 1.5	V
Short Circuit Current			±18			±18			±18		mA
DYNAMIC RESPONSE											
Small Signal −3 dB Bandwidth											
G = 1			1000			1000			1000		kHz
G = 10			800			800			800		kHz
G = 100			120			120			120		kHz
G = 1000			12			12			12		kHz
Slew Rate		0.75	1.2		0.75	1.2		0.75	1.2		V/µs
Settling Time to 0.01%	10 V Step										
G = 1–100			15			15			15		µs
G = 1000			150			150			150		µs
NOISE											
Voltage Noise, 1 kHz	Total RTI Noise = $\sqrt{(e^2_{ni}) + (e_{no}/G)^2}$										
Input, Voltage Noise, e_{ni}			9	13		9	13		9	13	nV/√Hz
Output, Voltage Noise, e_{no}			72	100		72	100		72	100	nV/√Hz
RTI, 0.1 Hz to 10 Hz											
G = 1			3.0			3.0	6.0		3.0	6.0	µV p-p
G = 10			0.55			0.55	0.8		0.55	0.8	µV p-p
G = 100–1000			0.28			0.28	0.4		0.28	0.4	µV p-p
Current Noise	f = 1 kHz		100			100			100		fA/√Hz
0.1 Hz to 10 Hz			10			10			10		pA p-p

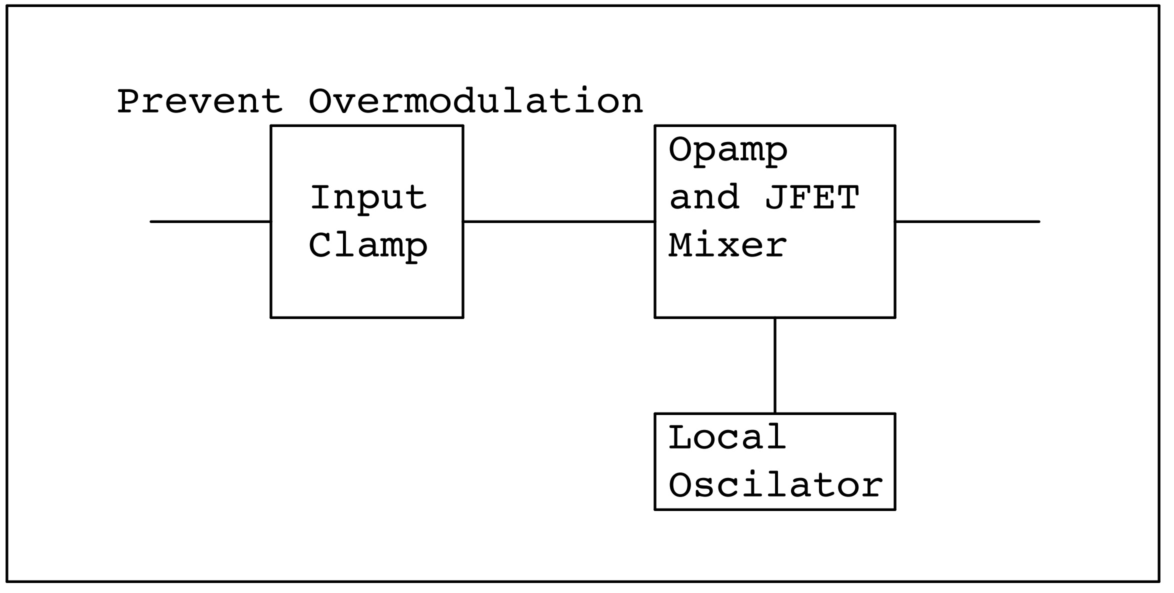
Linear Isolator Design



- Optoisolator with photodiodes on both sides of isolation barrier
- Very low bandwidth



AM Modulation



- Simple very low bandwidth AM modulation
- Reverse biased JFET as voltage controlled resistor to modulate amplifier gain.
- Linearity crucial. Why hit 40dB SNR if the EEG signal is ruined

Project Timeline