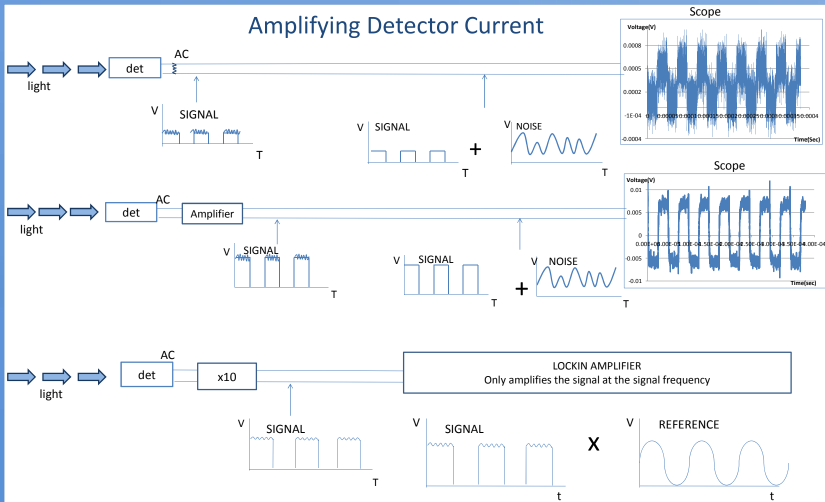
Catch the Signal

Zelu Xu - Sponsor : John Cerne

Introduction

•Different materials will respond differently to an polarized light, by measuring the intensity and polarization of light after it has interacted with a material, we can obtain new information insight into that material.
•A photodiode converts light into an output current.
•However, this current may be small and embedded in strong background noise.
• So we need to amplify this current before background noise overwhelms it and then pick out this signal from the noise.

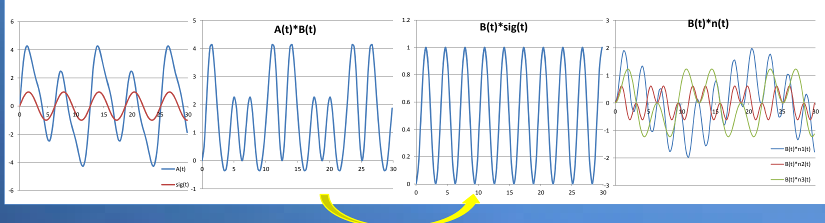
Amplifying Detector Current



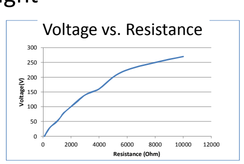
Method

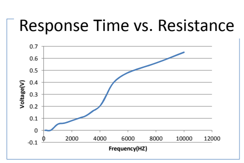
•Different approaches can be used to amplifier this voltage output. We can chose from the following two:
• Add a resister: V=I*R, as R increases , V also increases, but the response time will increase as well. This will not allow us to see fast signals.
• Add a pre-amplifier: using two op-amps in series we can increase the signal 200 -500 times with a faster response.
• Using a lockin amplifier, which locks on to the signal frequency, we can extract signals that are up to 10^5 times smaller than the background noise!

$A(t) = Sig(t)+N1(t)+N2(t)+N3(t)$,
where $Sig(t)=A_{sig}\sin(\omega_{sig}t)$, $N1(t) = A_{N1}\sin(\omega_{N1}t)$, $N2(t) = A_{N2}\sin(\omega_{N2}t)$, $N3(t) = A_{N3}\sin(\omega_{N3}t)$;
If we choose $B(t)=\sin(\omega_{sig}t)$, $\int[A(t)*B(t)]dt = \int[Sig(t)*B(t)]dt \propto A_{sig}$; $\int[Nx(t)*B(t)]dt = 0$;
Thus, we can pick out the signal.



Response from different resistance

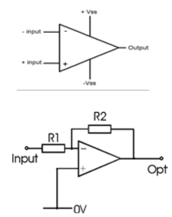




Basic laws of amplifier

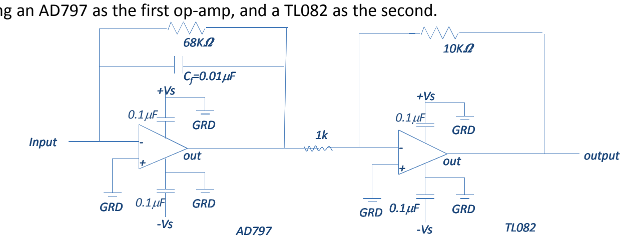
1. The op-amp inputs draw no current
2. The op-amp output will provide feedback to the input to keep $+V_{in}= -V_{in}$

Thus, when we add resisters, it will amplifier the output by a gain G=-R2/R1
By connecting two op-amps, we will be able to get the appropriate gain

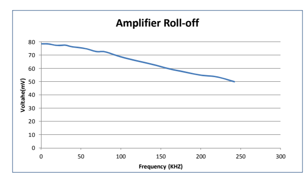


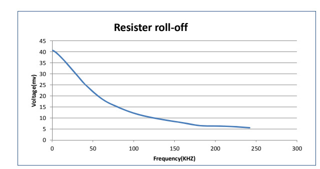
Designed circuit

• The detector current flows through the 68kΩ resistor.
•The 0.01 μF feedback capacitor C_f in parallel with this resistor helps to short out high frequency noise and oscillations in the feedback circuit.
• The following equation can be used to choose the feedback capacitance across the first op-amp: $C_f=1/2\pi fRf$, where f=300kHz
• An excessively large gain will slow down the response time, so we apply gain in two stages, using an AD797 as the first op-amp, and a TL082 as the second.



Results





•From the figures we can see, the resister begins to roll-off before amplifier with a deeper slope. This indicates that the response time of resister will be larger than the amplifier, if the two systems were maintained at the same scale of signal's magnitude.

432 Ohm Resistor		Amplifier	
Mag (μV)	θ (deg)	Mag (mV)	θ (deg)
430	5.32	14.1	7.2
420	7.06	14.1	9.04
422.4	7.39	13.9	9.61
415.6	8.29	13.7	13.25
407.9	9.16	13.45	19.24

•From the table we can see, for similar roll-off, the magnitude of the resistor's signal will be about 300 times smaller than the amplifier system.

Conclusion

• A two-stage amplifier can increase the signal by a factor of 300 while maintaining a fast response time (bandwidth >200 kHz)
• Compared to a simple resistor circuit, the amplifier's response time is smaller for the same amount of gain, with a 30% drop in signal occurring at 200kHz for the amplifier compared to 40kHz for the resistor.
• By adding a lockin amplifier, we can dramatically reduce the noise to the point where we can find the signal buried in noise as one would find a needle buried in a haystack.

Acknowledgements

This research was supported by the National Science Foundation. I wish to thank John Cerne

Introduction

- Different materials will response differently to an polarized light, by analysis this signal, we can obtain information of the material’s property.
- A Photo detector can detect this light as an input and transfer to a current output.
- However, this current is too small, with too much noise for analyzing.
- So, we need to amplifier this current!!

Abstract

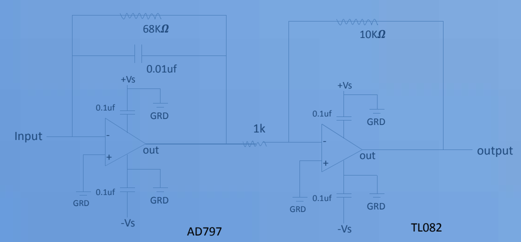

Scope
DC
det
light
V
SIGNAL
T
V
SIGNAL
+
V
NOISE
T
Scope
DC
det
x10
light
V
SIGNAL
T
V
SIGNAL
+
V
NOISE
T
Scope
AC
det
x10
LOCKIN
Only amplifier the right frequency
light
V
SIGNAL
T

Method

- Different ways can be applied to amplifier this voltage output. We chose the following two:
- Add a resister: V=I*R, as R increase, V increase; but the response time will increase as well;
- Add an pre-amplifier: connecting two op-amps and we can increase the signal 500 -1000 times with a faster response.

Response for different resistance


Scope
AC
det
x10
LOCKIN
Only amplifier the right frequency
V
T
light
V
SIGNAL
T


68KΩ
0.01uf
10KΩ
+Vs
0.1uf
GRD
Input
out
1k
output
-Vs
AD797
TL082