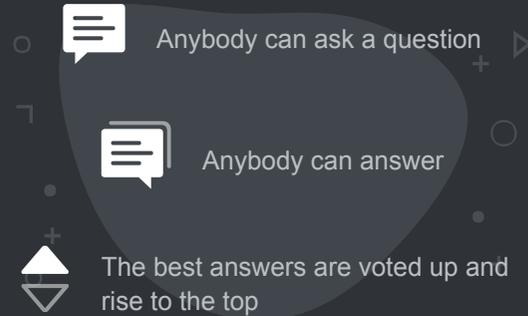


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## Operational amplifier as a comparator at high frequency

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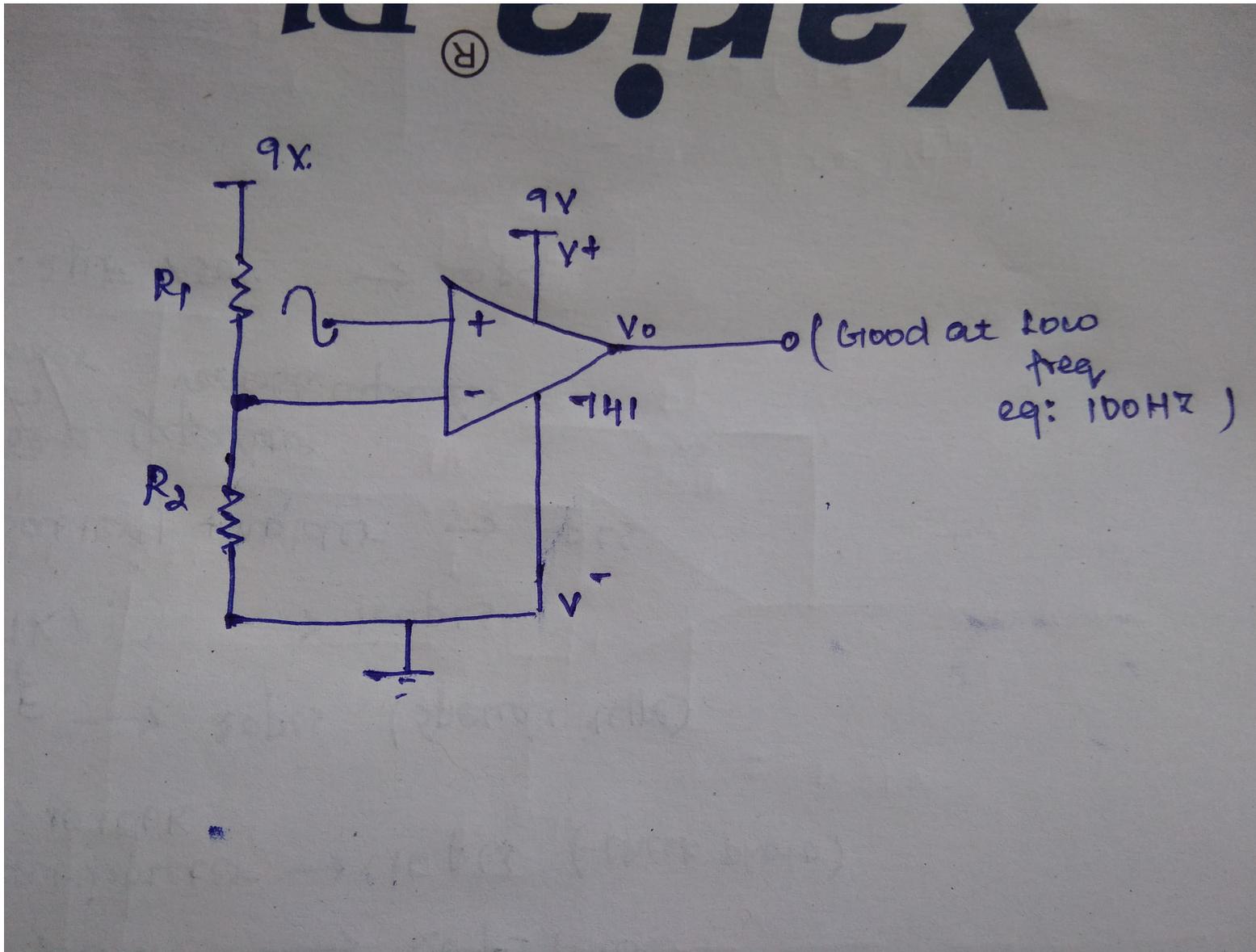
6

I am trying to generate a sinusoidal PWM signal using analog circuits. I want to compare my sine wave and triangular wave using an operational amplifier (LM741) which has a rise time of  $0.3 \mu\text{s}$  and slew rate  $0.5 \text{ V}/\mu\text{s}$ , which will good at 5 kHz theoretically. But I am not getting a good PWM output.

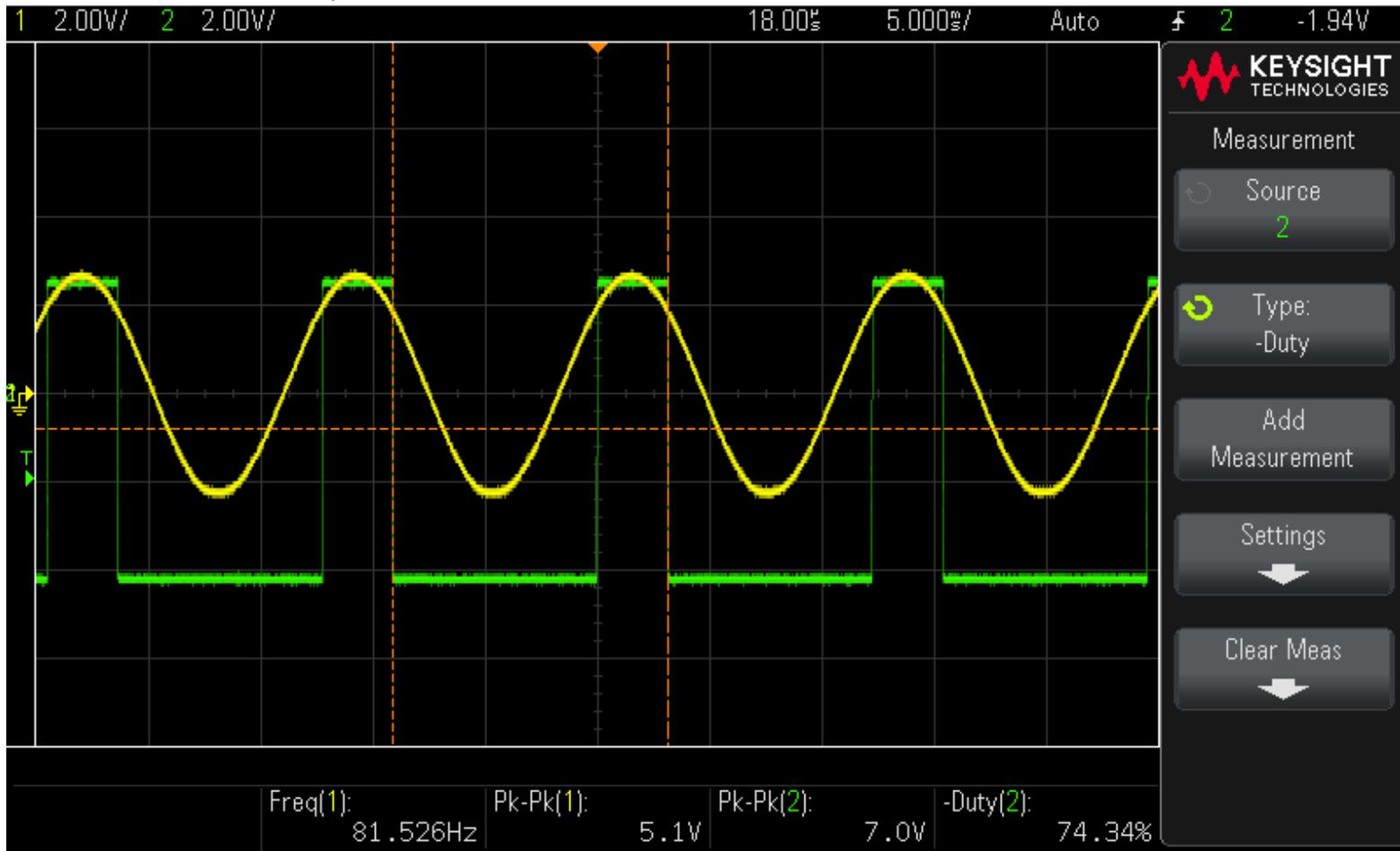


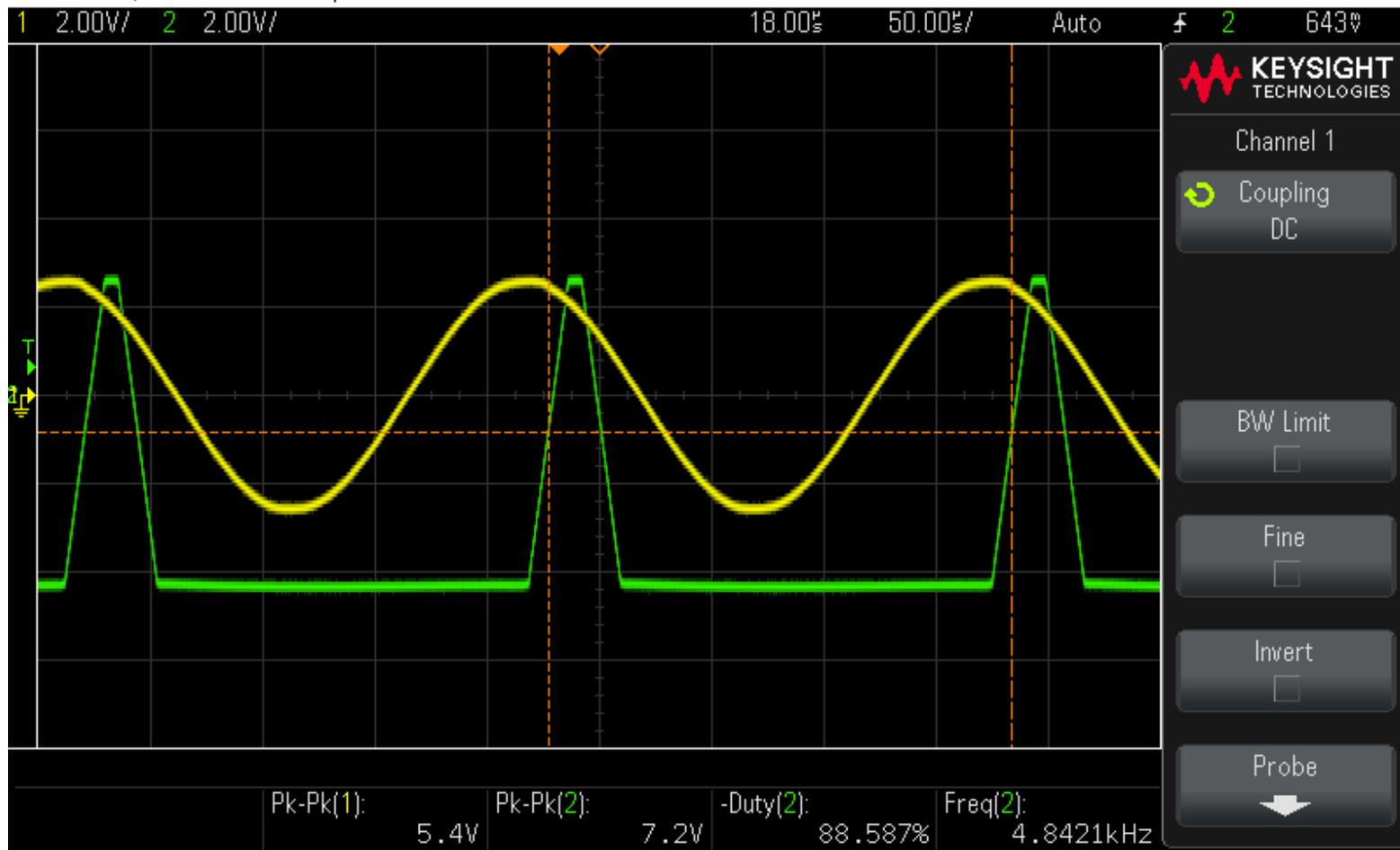
So I first tried to compare the sine wave with a reference voltage (2.2 volt). Sine wave amplitude = 2.5 volt (5 V peak to peak) and frequency 100 Hz and 5 kHz.





- At low frequency (say 100 Hz), the output is good
- At high frequency (say 5 kHz), the output is too bad.





### What will be the problem...

If the response is the problem of the comparator, but the slew rate is  $0.5 \text{ V}/\mu\text{s}$ .

*Calculation of slew rate for a sinusoidal signal...*

Slew rate =  $V_m * 2\pi * \text{Frequency}$

$$= 5 \text{ V} * 2\pi * 5000 \text{ Hz}$$
$$= 1570796 \text{ volt per second or } 0.15 \text{ V}/\mu\text{s}$$

Theoretically the slew rate of  $0.5 \text{ V}/\mu\text{s}$  will be OK for a sinusoidal signal of 5 kHz and 5 volt peak to peak. But in my case the signal is distorted.

Where am I wrong?

operational-amplifier

comparator

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edited Apr 5 '19 at 19:15



Peter Mortensen

1,619 ● 3 ● 15 ● 22

asked Apr 5 '19 at 10:51



Bud

199 ● 10

It looks like there's a significant lag/delay in the output's response w.r.t. the input signal ( $\sim 30\mu\text{s}$ ). What may be causing this? What's connected to the output? 'Scope probe only? – JimmyB Apr 5 '19 at 11:00

5 [Why you shouldn't use the 741.](#) – JRE Apr 5 '19 at 11:16

For 5Khz i thought 741 will be ok, for what i calculated .Orelse sure i will change the opp amp which having high slew rate and i will update it.....@JRE – Bud Apr 5 '19 at 11:26 ✎

Yes i used the scope probe only at the output. I don't know which causing this error.....@Jimmy – Bud Apr 5 '19 at 11:28

1 You're latching up. – Scott Seidman Apr 5 '19 at 12:34

2 Note that this question is about the theory behind the calculations. Telling OP to change his OP-amp does nothing to answer the question. It just solves the problem without OP knowing why. – pipe Apr 5 '19 at 19:58

If not latching you are at least saturating and the recovery takes time. A 741 is a poor comparator and an OP-AMP over driven rail to rail is not able to operate to small signal design specifications. You are also at the low end for 741 supply headroom. – KalleMP Apr 5 '19 at 20:13

The slew rate of a square wave is infinite. So a slew-rate limited op-amp will not put out a square wave. It will put out a "trapezoid" wave, which is what you are seeing. The question you should ask is, does the slew rate of your trapezoid match the specification? Looks like not. It is too slow by far. But I just wanted to point out that your frequency calculation is really not applicable when the expected output is a square wave. – mkeith Apr 8 '19 at 9:12

add a comment

## 5 Answers

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The recommendations for you are very simple.

11

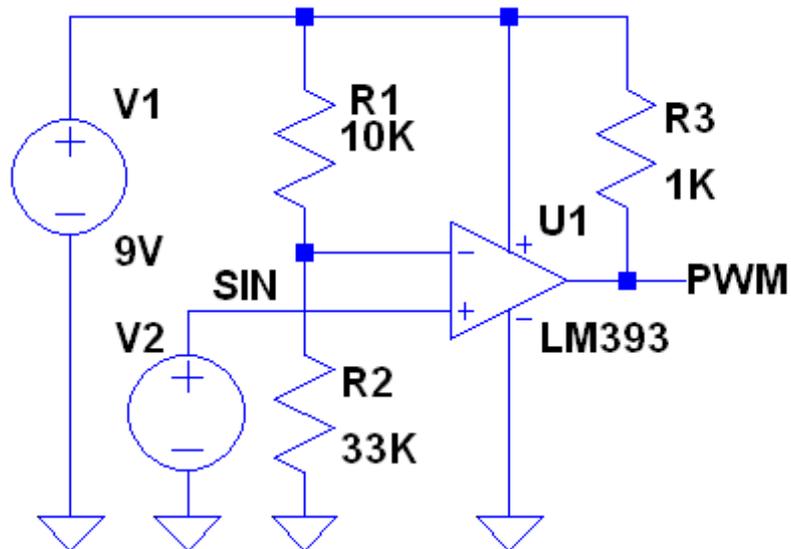
1. Use a comparator for this application instead of an opamp.
2. Select a newer part that operates with orders of magnitude faster response time.



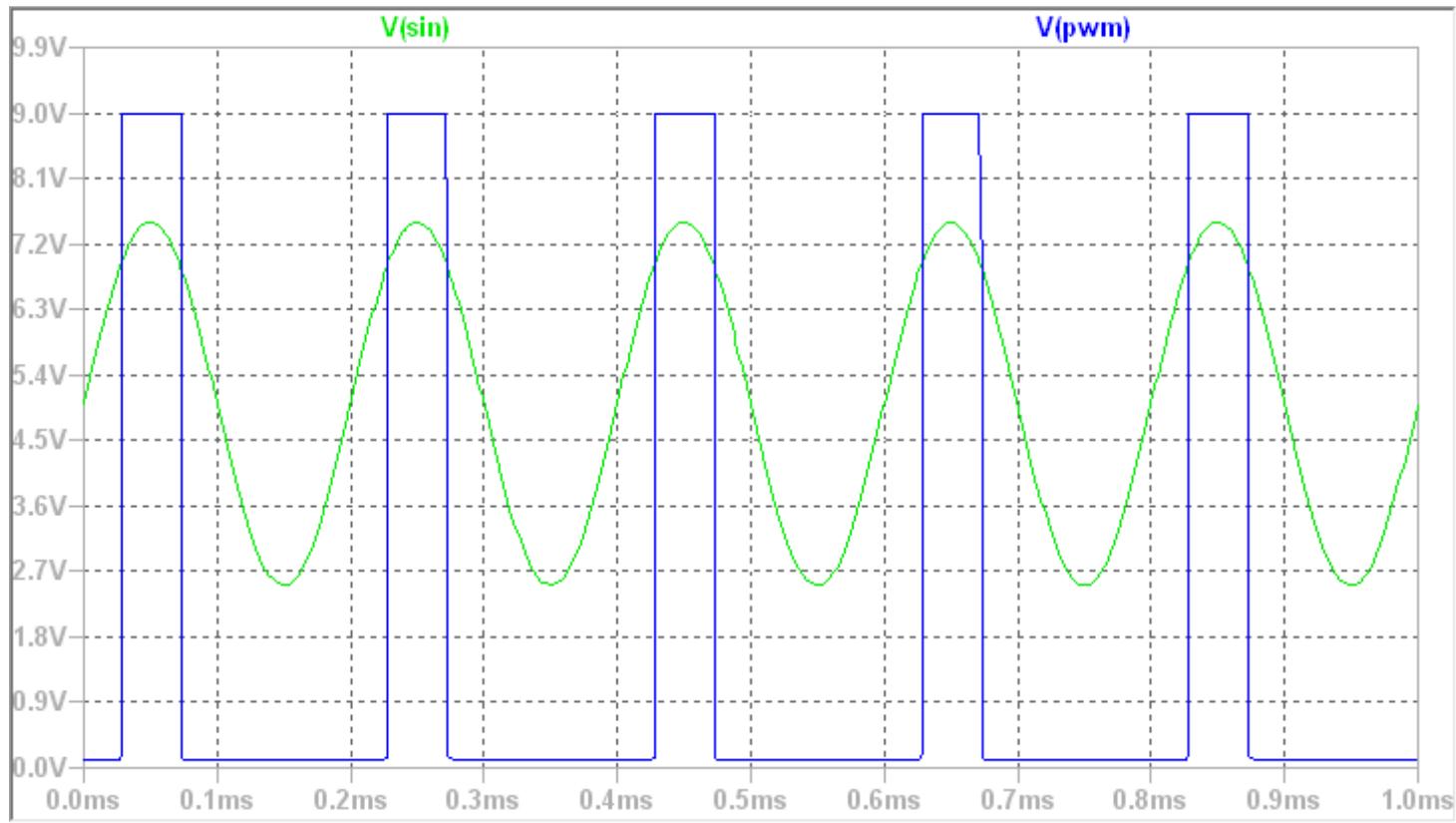
It would be the very best thing if the 741 could be eradicated from face of the earth.



Here is what can be achieved with the venerable LM393 at 5kHz. The shown circuit will work even up to about 50kHz before the delay of the LM393 starts to distort the PWM duty cycle.



```
SINE(5V 2.5V 5000Hz)  
.include LM393.5_1
```



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edited Apr 5 '19 at 11:52

answered Apr 5 '19 at 11:03



Michael Karas

51.7k ● 3 ● 54 ● 118

Sure friend i will change the opp amp or by using comparator, i will update the data soon. – Bud Apr 5 '19 at 11:33

1 @Nihal - If you show some new results in the question do not delete your original material, Instead add it as an update at the end. The reason for this is that hopefully this question can be a reference to future readers that are looking for information as being discussed here. If you delete the original material the answers here would no longer make much sense to a future reader. – Michael Karas Apr 5 '19 at 11:47

1 "It would be the very best thing if the 741 could be eradicated from face of the earth." ok - I'll bite. what's your reasons? – UKMonkey Apr 5 '19 at 15:35

2 @UKMonkev the 741 was first released in 1968. And while it was a fantastic IC at the time. there are vastly superior op-amps

2 @Stamenkey the 741 was first released in 1969, and while it was a landmark IC at the time, there are really superior op-amps available with lower input offset voltage, higher bandwidth, higher input impedance, etc. Most people lean the "ideal op-amp" first, and then immediately jump to one of the most non-ideal op-amps in practice, and wonder why their design doesn't work. – [CurtisHx](#) Apr 5 '19 at 16:10

LM741 might still be in the textbooks... – [Peter Mortensen](#) Apr 5 '19 at 16:19

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Opamps work slowly with low power supply voltages. In addition they are designed to work in linear region. As saturated, like in your application, the response has an unpredictable dead time. before the internal saturation is vanished.



I can only repeat what's already said: Get a comparator. 741 was a remarkable step forward half a century ago, but things have developed better since those days.



share improve this answer follow

answered Apr 5 '19 at 11:09



[user287001](#)

14.3k ● 2 ● 8 ● 25

Thank you for your response friend, i will update it after changing the opp amp. – [Bud](#) Apr 5 '19 at 11:29

2 @Nihal Comparators have other precautions. They are high speed circuits like logic parts. You must have acceptably short wires and coupling capacitors between supply voltage inputs. Making the circuit with 0,5 meter long wires onto a breadboard without coupling caps (I have seen those attempts) will be useless. – [user287001](#) Apr 5 '19 at 11:39

Ok friend I will even buy a comparator and I will check with it. – [Bud](#) Apr 5 '19 at 18:34

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Op-amps are susceptible to [latch-up](#). Recovering from saturation at the rails is not an automatic thing. The ratings you are reading a for the op amp working in a feedback mode, not an open loop mode. You would need to find an op amp designed to minimize latch-up, or better yet, when you need a comparator, buy a comparator.



share improve this answer follow

answered Apr 5 '19 at 12:33

[Scott Seidman](#)



26k ● 4 ● 35 ● 98

1 Yes, and/or [phase inversion](#), depending on the op-amp type. – [Peter Mortensen](#) Apr 5 '19 at 17:10

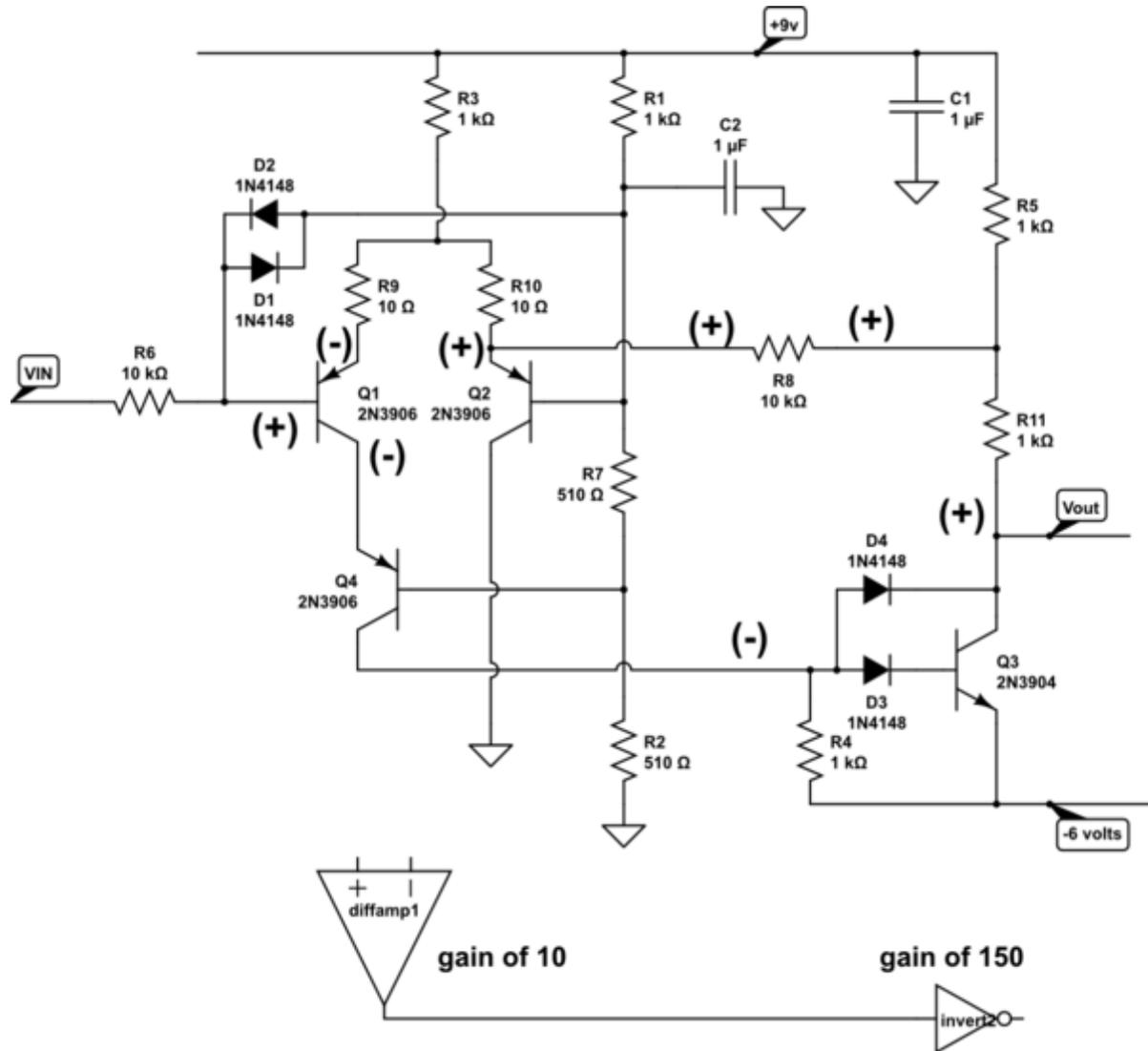
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[modified to run on +9/-6 volt rails] You may try this, if you want a discrete solution. The delay, without input protection resistor, should be about 20 nanoseconds.

1





[simulate this circuit](#) – Schematic created using [CircuitLab](#)

The speed will be limited by Rin (10Kohm) and a minimal Miller Effect Cin (20pF?), thus propagation delay will be about 0.2 us (200 nanosecond).

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edited Apr 8 '19 at 8:13

answered Apr 5 '19 at 15:59

What is it? A [Schmitt trigger](#)? – Peter Mortensen Apr 5 '19 at 16:21

The differential pair is biased at  $V_{DD}/2$ . R8 does provide 1% positive feedback, to reduce the risk of oscillation during the linear region. Notice I included over-voltage protection. – analogsystemsrf Apr 6 '19 at 3:28

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Most garden variety op-amps have internal compensation in the form of a chip capacitor.

0

This makes them very slow, but more stable in analog circuits.



Why not use a cheap comparator like [LM393](#)?



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edited Apr 5 '19 at 14:25



[Renan](#)

4,693 ● 2 ● 23 ● 45

answered Apr 5 '19 at 11:04



[Autistic](#)

9,902 ● 2 ● 20 ● 43

Thank you friend it works good while using comparator LM339. – [Bud](#) Apr 8 '19 at 6:45

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