TECHNICAL UNIVERSITY OF CLUJ-NAPOCA ROMANIA

Pulse-Width-Modulation Generator

Project realized by

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Group 2023

Guiding professor

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1. Introduction

1.1 About OrCad

OrCAD is a suite of products for PCB Design and analysis that includes a schematic editor (Capture), an analog/mixed-signal circuit simulator (PSpice) and a PCB board layout solution (PCB Designer Professional).[8]

OrCAD Capture is a schematic capture application, and part of the OrCAD circuit design suite.

A circuit to be analyzed using PSpice is described by a circuit description file, which is processed by PSpice and executed as a simulation. PSpice creates an output file to store the simulation results.

The type of simulation performed by PSpice depends on the source specifications and control statements. PSpice supports the following types of analyses:

- **DC Analysis** - for circuits with time–invariant sources (e.g. steady-state DC sources). It calculates all nodal voltages and branch currents over a range of values. Supported types include Linear sweep, Logarithmic sweep, and Sweep over List of values.[8]
- **Transient Analysis** - for circuits with time variant sources (e.g., sinusoidal sources/switched DC sources). It calculates all nodal voltages and branch currents over a time interval and their instantaneous values are the outputs.[8]
- **AC Analysis** - for small signal analysis of circuits with sources of varying frequencies. It calculates the magnitudes and phase angles of all nodal voltages and branch currents over a range of frequencies.[8]
- **Parametric Analysis** - performs multiple iterations of a specified standard analysis while varying a global parameter, model parameter, component value, or operational temperature. The effect is the same as running the circuit several times, once for each value of the swept variable.[9]
- **Performance Analysis** - uses measurement definitions to scan a family of curves in Probe and to return a series of values based on the measurement definition. After sweeping a voltage source connected to a CR network, a series of capacitor voltage charging curves are to be obtained. Running a performance analysis using the rise time measurement definition on the resulting waveforms generates a series of rise time values plotted against the swept source voltage.[10]

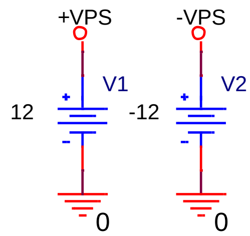
1.2 Project Requirements

It is required to design a **Pulse-Width-Modulation (PWM) Generator**, using the OrCad design environment, following the requirements seen in *Table 1*.

Duty Cycle	60 – 80%
Amplitude	1 - 6 V
Frequency	600 Hz

Table 1

There were no specified values for the voltage power supplies so I chose to use ±12V for +VPS, respectively for -VPS.



2. Theoretical approach

2.1 What is a PWM generator

A Pulse Width Modulation (PWM) Signal is a method for generating an analog signal using a digital source. A PWM signal consists of two main components that define its behavior: a duty cycle and a frequency.

- The duty cycle describes the amount of time the signal is in a high (on) state as a percentage of the total time of it takes to complete one cycle.
- The frequency determines how fast the PWM completes a cycle (i.e. 1000 Hz would be 1000 cycles per second), and therefore how fast it switches between high and low states.

By cycling a digital signal off and on at a fast enough rate, and with a certain duty cycle, the output will appear to behave like a constant voltage analog signal when providing power to devices [2].

2.2 Working principle

Pulse Width Modulation (PWM) is a technique to generate low frequency output signals from high frequency pulses. Rapidly switching the output voltage of an inverter leg between the upper and lower DC rail voltages, the low frequency output can be thought of as the average of voltage over a switching period.

Besides that, there are also other several ways of generating pulse-width modulated signals, including analog techniques, sigma-delta modulation, and direct digital synthesis.

One of the simplest methods of generating a PWM signal is to compare two control signals, a carrier signal and a modulation signal. This is known as carrier-based PWM. The carrier signal is a high frequency (switching frequency) triangular waveform. The modulation signal can be any shape.

Using this approach, the output waveform can be a PWM representation of any desired waveform shape. With machines, sinusoidal and trapezoidal waveform shapes are among the most common.

2.3 Applications of PWM generators

PWM signals are used for a wide variety of control applications. Their main use is for controlling DC motors but it can also be used to control valves, pumps, hydraulics, and other mechanical parts. The frequency that the PWM signal needs to be set at will be dependent on the application and the response time of the system that is being powered. Below are a few applications and some typical minimum PWM frequencies required:

- Heating elements or systems with slow response times: 10-100 Hz or higher
- DC electric motors: 5-10 kHz or higher
- Power supplies or audio amplifiers: 20-200 kHz or higher

3. Schematic

3.1 Initial Schematic

The **initial** electrical scheme for a PWM generator, the one I presented in "Project part 1", is illustrated in *Figure 1*. [1][3]

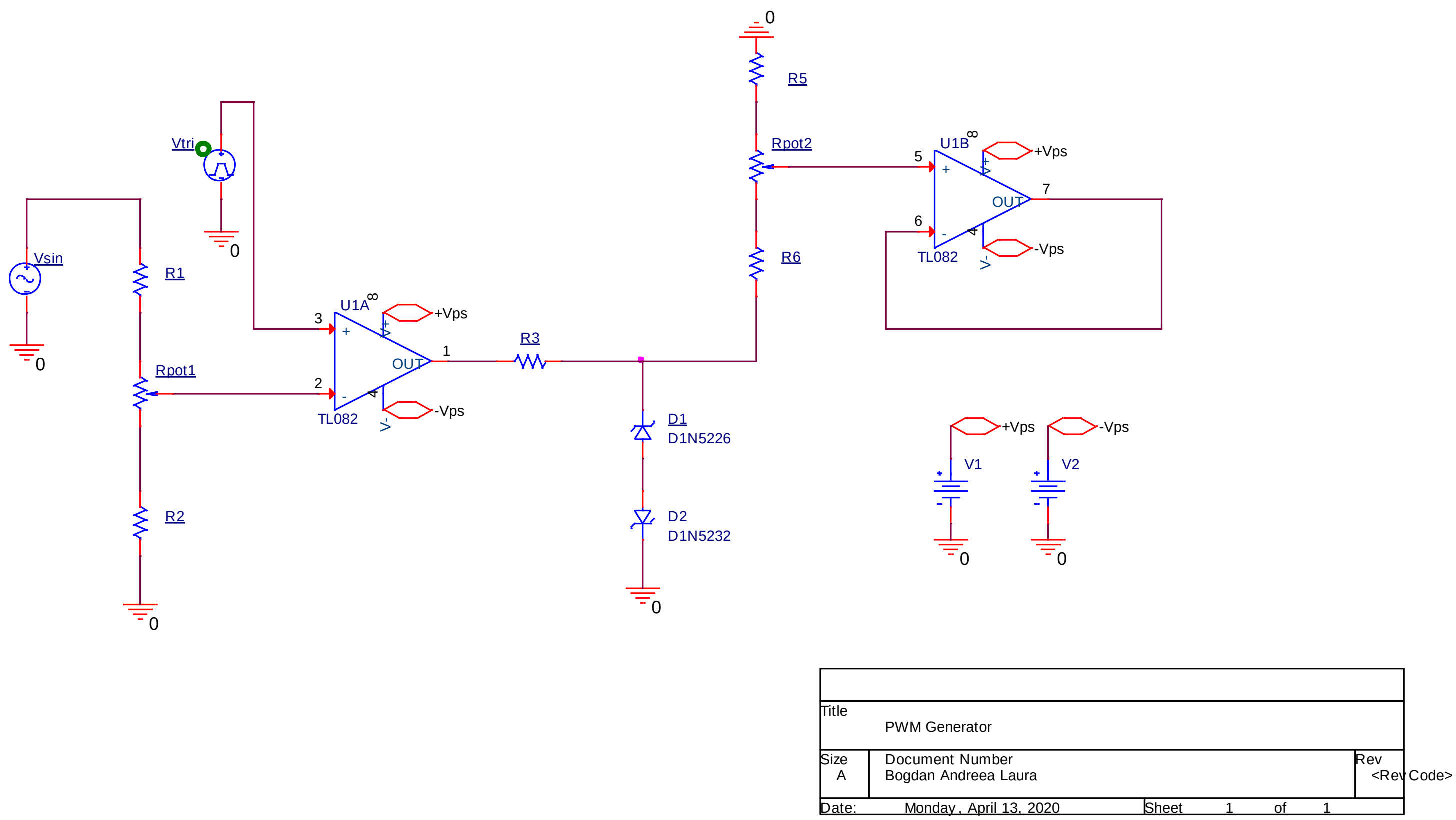


Figure 1.

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3.2 Previous Schematic

The **previous** electrical scheme for a PWM Generator is illustrated in *Figure 2*.

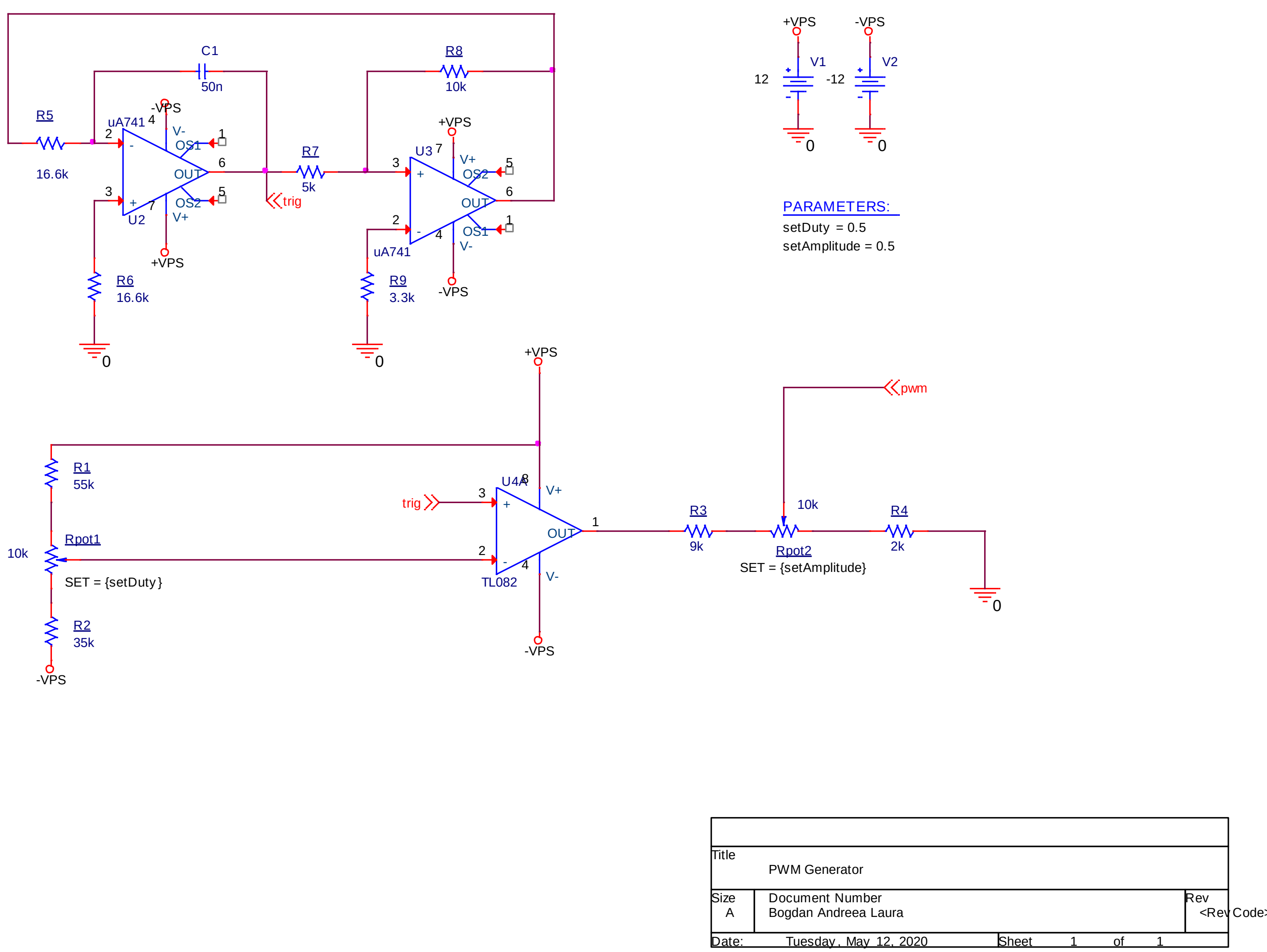
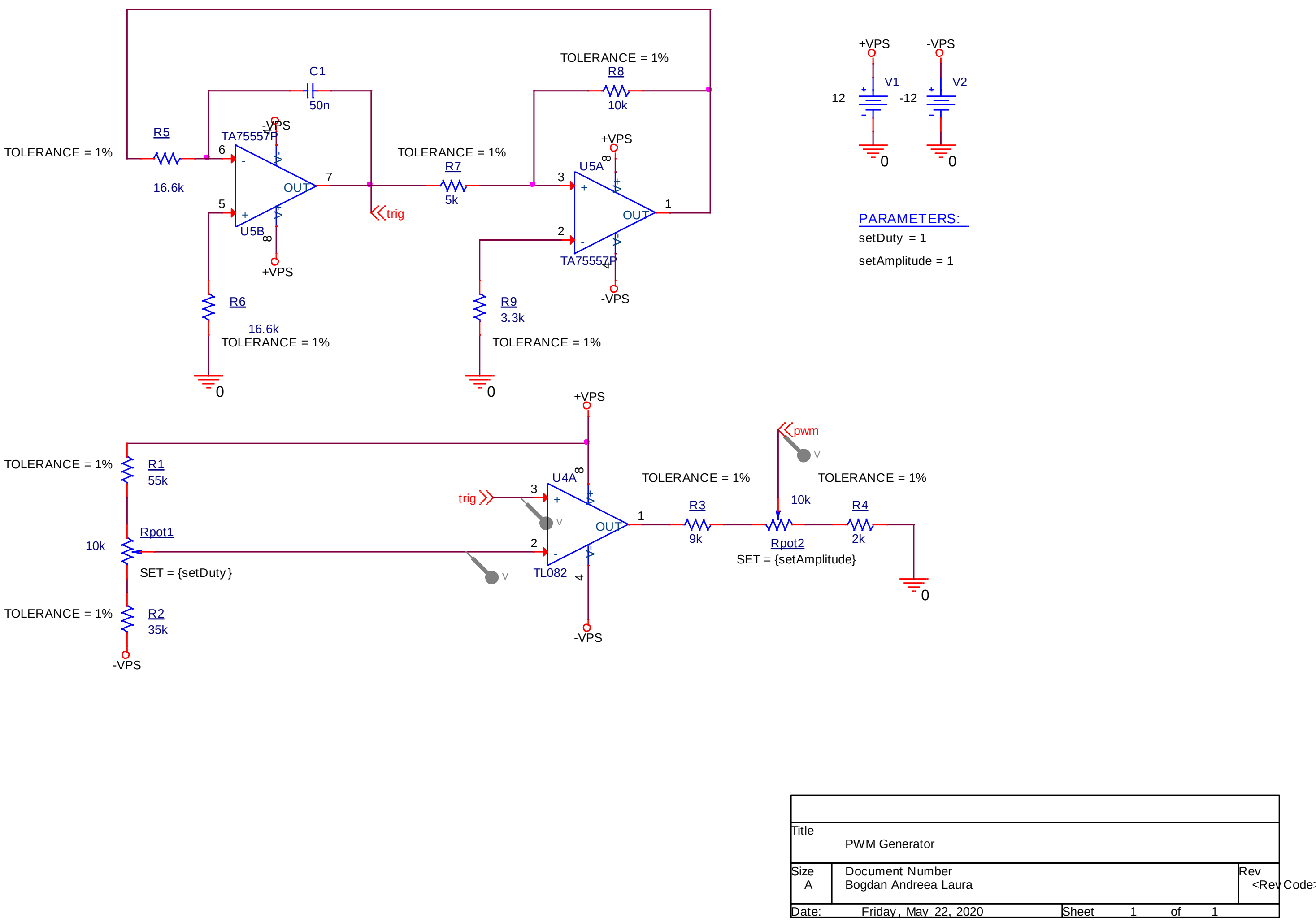


Figure 2

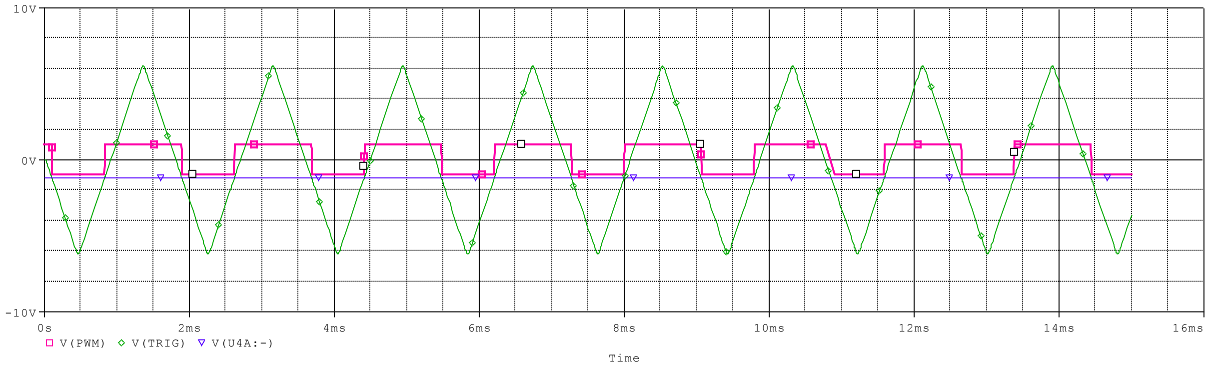
The reason why I chose to modify the previous schematic, the one shown in *Figure 1*, almost entirely is because it did not meet some requirements.

- Instead of using an external voltage source, the VPULSE source, for my triangular signal, I replaced it with an astable multivibrator, made of an integrator and comparator. It generates a triangular and a rectangular signal, which combined with the comparator *U4* generates the PWM signal.
- Also, I decided to get rid of the VSIN voltage source, and connect the voltage divider containing the potentiometer *Rpot1* directly to ±VPS, to help me make the duty cycle adjustable.
- I chose not to use the voltage regulator made out of the two diodes, *D1* and *D2*, because it was no longer of use.
- I had to eliminate *U1B* from my previous schematic as well, because I came to realize that it didn`t do anything and it did not affect my signal in any way.

3.3 Actual Schematic



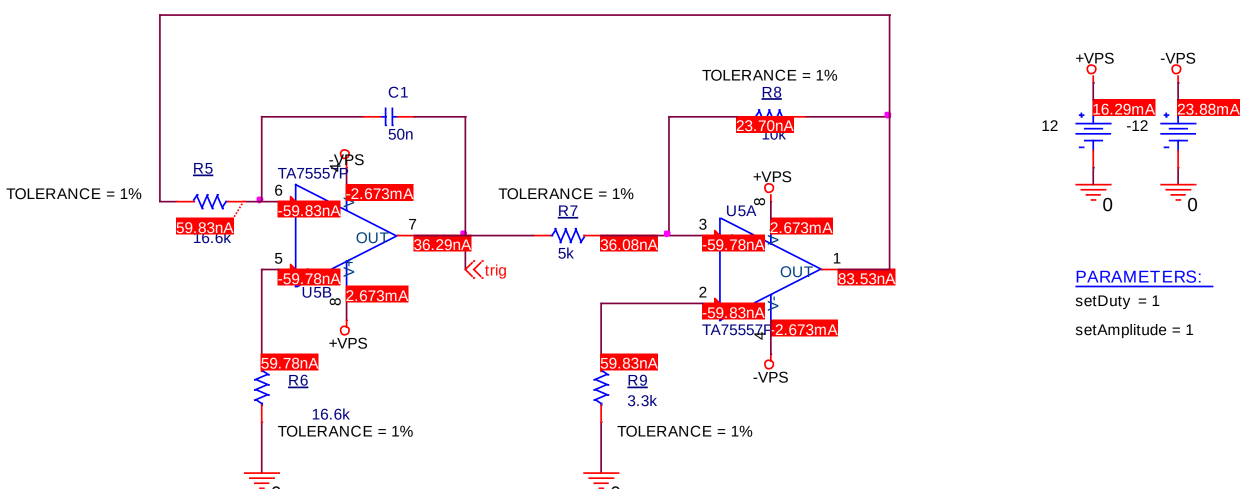
- What differes from this schematic, the actual one, to the one I presented in “Project part 2”, is that I replaced the uA741 operational amplifiers with a different type, TA75557P.
  The reason why I did this is because the new opamp is more right for my circuit.
  With the opamp uA741 my signal didn`t look exactly as it should. The amplitude of the triangular signal exceeded 6V , the value which I calculated, by 3%. Also, it looked quite sinusoidal in some parts, as can be seen below:



The slew rate of the opamp uA741 is 0.5V/us, so I tried to find an op amp with a little bit bigger slew rate so that my signal doesn't get distorted. I chose to work with the opamp TA75557P. It has a slew rate of 1V/us which is big enough form my signal to not have distortions.

By running a Bias Point simulation (figure below) it can also be observed that the values in my circuit respect the specifications in the OpAmp's datasheet.

- ⇨ The maximum values of the supply sources a specified to be ±18V. Mine are ±12V.
- ⇨ The input bias current, which is the current that flows into the inputs of the opamp, should not exceed 500nA. Mine are -59.78nA and -59.83nA.
- ⇨ Supply current, Icc, which is the current which flows through the supply sources in the opamp, should not exceed 6mA. Mine is, for +VPS, 2.672mA.



4. Block diagram and circuit functionality

4.1 Block diagram

The block diagram for the PWM Generator is shown below, in *Figure 3*.

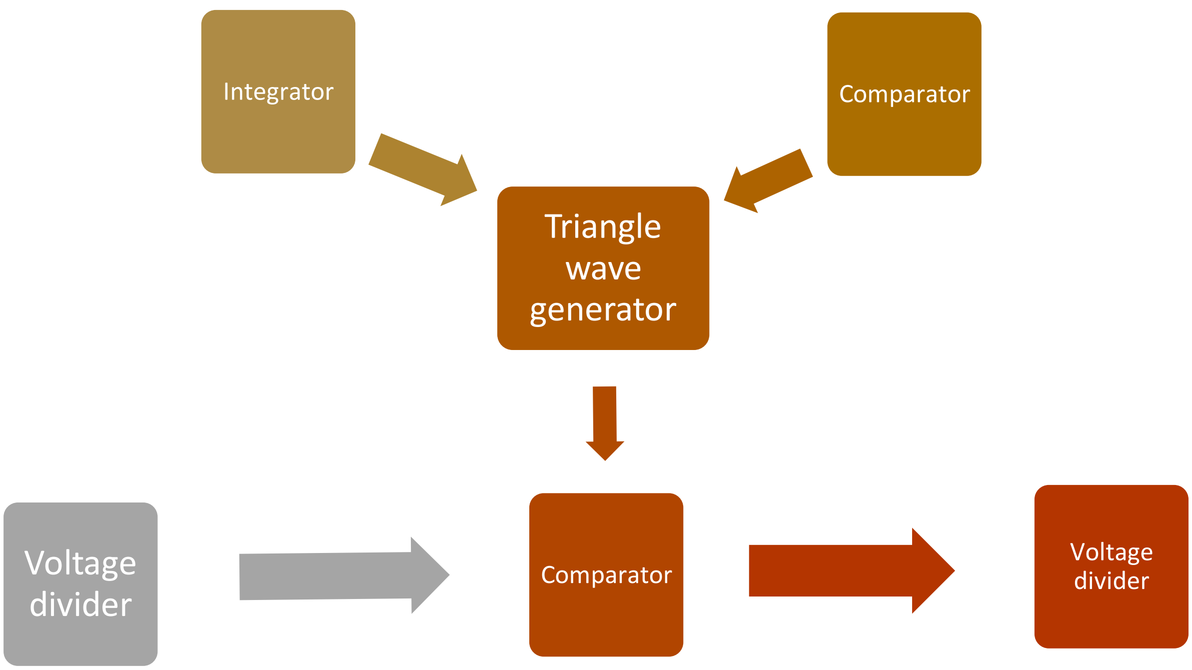


Figure 3.

- The integrator combined with the comparator forms the triangle wave generator, which generates a triangular and rectangular signal;
- The first voltage divider, containing the potentiometer *Rpot1*, makes the adjustment of the duty cycle between 60% - 80% possible;
- The voltage comparator then receives the signal generated by the triangle wave generator and and a reference voltage, the one from the first voltage divider, compares them and generates the pwm signal.
- The second voltage divider, containing the potentiometer *Rpot2*, adjusts the amplitude of the pwm signal, which is the rectangular signal, between the interval [1V, 6V], according to the project requirements.

4.2 Circuit functionality

For the realization of the PWM generator, I have used the following components:

- 9 resistors;
- 1 capacitor;
- 2 potentiometers;
- 2 operational amplifiers of the type TA75557P;
- 1 operational amplifier of the type TL082;
- 2 DC voltage sources for the power supplies.

4.2.1 Triangle wave generator

The part of the circuit which generates the triangular signal is presented in *Figure 4* [6].

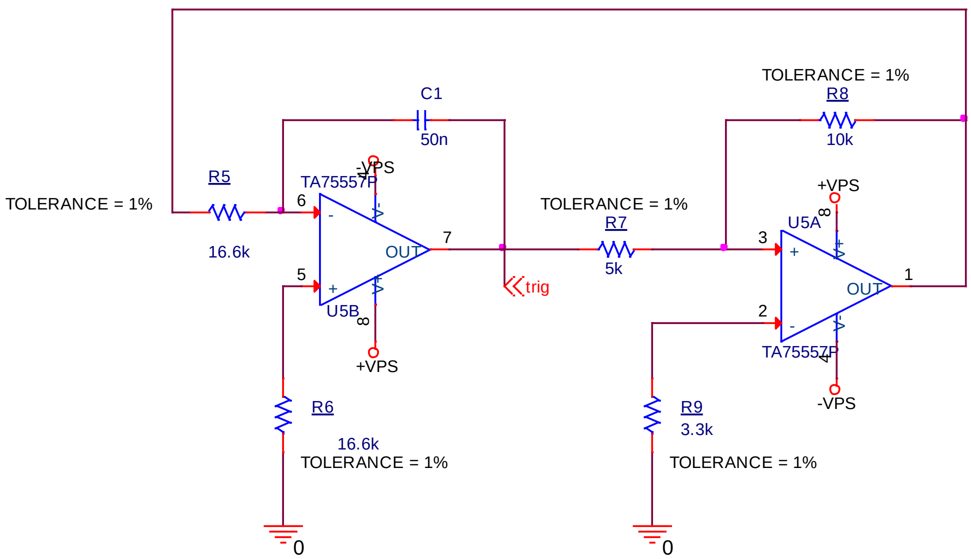


Figure 4. Triangle Wave Generator

As a triangular wave generator I have used and Astable Multivibrator made of an integrator and a comparator. The inverting input of the operational amplifier *U2* is connected to the output of the operational amplifier *U3*, and thus creating a connection between the integrator and the comparator.

The output of *U2* generates the triangular signal and the rectangular signal is given at the output of *U3*, when the voltage across the capacitor is fed to the comparator. The frequency of the signals is equal to 1/T, T being the period. This circuit needs to have the frequency equal to 600Hz. The components that give us the period (T) of the signals are the resistors *R5*, *R6*, the capacitor *C1* and the fraction between *R7* and *R8*. Given the fact that *R5* and *R6* need to be equal, the formula looks like this [6]:

$$T = 4 \cdot R5 \cdot C1 \cdot \frac{R7}{R8} \tag{1}$$

The amplitude of the triangular signal [6] is given by the fraction between *R7* and *R8*, multiplied by the voltage power supplies, ±*VPS*.

$$A_{trig}min = -\frac{R7}{R8} \cdot (+VPS)$$

$$A_{trig}max = -\frac{R7}{R8} \cdot (-VPS)$$

[6] (2)

4.2.2 The voltage comparator and the first voltage divider

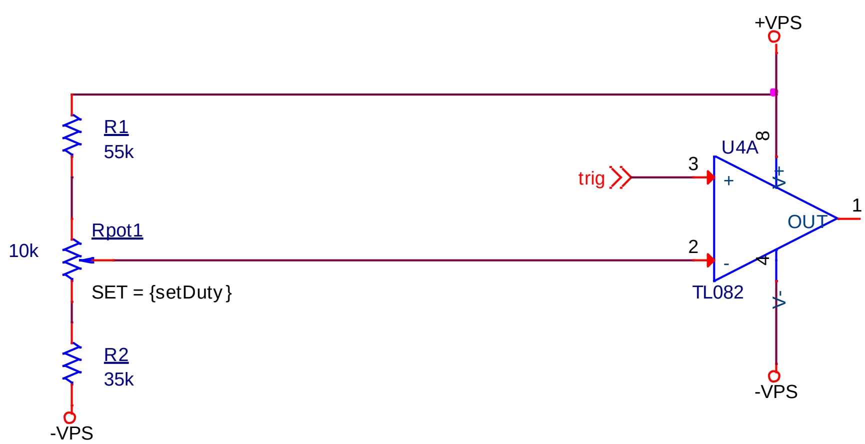


Figure 5. Voltage divider for Duty Cycle adjustment and a voltage comparator

The voltage divider which has the two resistors, *R1* and *R2*, connected in series with the potentiometer *Rpot1*, helps us set the duty cycle and make it adjustable in the given interval, [60% - 80%]. When the potentiometer is turned all the way down (*setDuty*=0), the duty will be 60%. This means that the PWM signal will be logic '1' for 60% of the whole period T, *Figure6* [12]. On the other hand, when the potentiometer is turned all the way up, (*setDuty*=1), the PWM signal will be logic '1' for 80% of the period, *Figure7* [13].

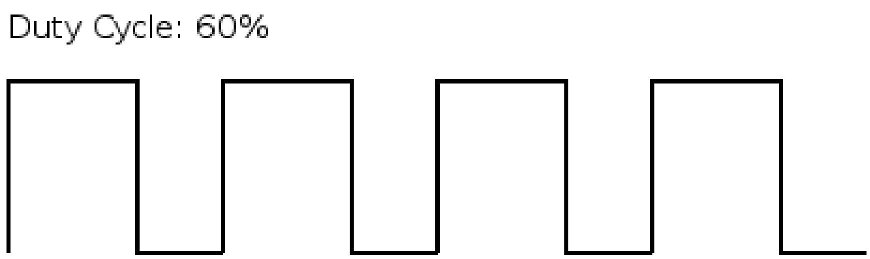


Figure 6. Example of a 60% Duty Cycle

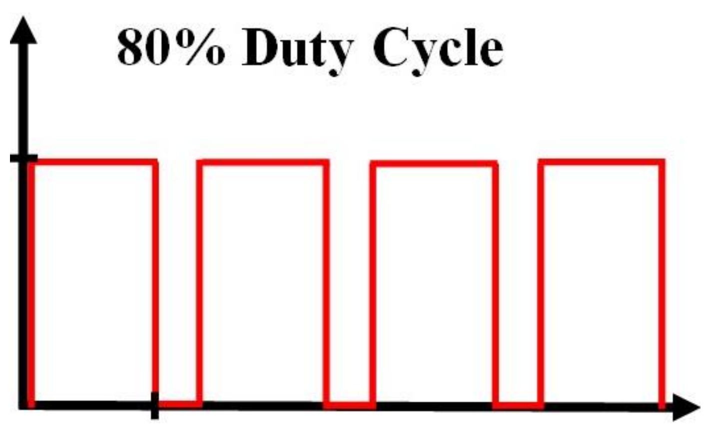


Figure 7. Example of an 80% Duty Cycle

For this to be possible, the resistors are connected to ±*VPS* and the voltage divider is connected to the inverting input of the operational amplifier *U4A*.

The operational amplifier *U4A* plays the role of a voltage comparator. Besides its inverting input, where the first voltage divider is connected, we have the non-inverting input, where the output from the integrator of the triangular wave generator is connected. Thus, this comparator receives the triangular signal and the reference voltage generated by the voltage divider, compares them and then generates the PWM signal.

4.2.3 Second voltage divider

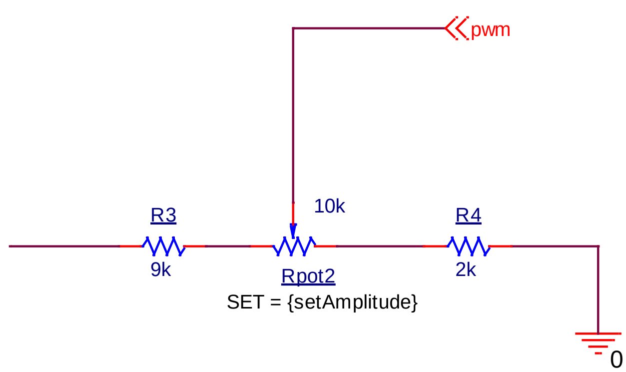


Figure 8. Voltage divider for amplitude adjustment

The use voltage divider connected at the output of the voltage comparator *U4A* is to set and adjust the amplitude of the PWM signal in the required interval [1V – 6V]. When *Rpot2* is turned all the way down (setAmplitude=0) the amplitude of the signal will be 1V, and when turned all the way up, (setAmplitude=1), the amplitude of the PWM signal is 6V.

5. Formulas and calculated values

For the power supplies, ±*VPS*, I have chosen ±12V. Also, for the capacitor *C1* I chose the value of 50nF.

5.1 Amplitude of the Triangular Signal

Chosen values: R7 = 5kΩ

R8 = 10kΩ

- For the min amplitude of the triangular signal we use the formula[6]:

$$A_{trig}min = -\frac{R7}{R8} \cdot (+VPS)$$

⇨ $\mathbf{A_{trig}min} = -\frac{5k}{10k} \cdot 12V = \mathbf{-6V}$

- For the max amplitude of the triangular signal we use the formula[6]:

$$A_{trig}max = -\frac{R7}{R8} \cdot (-VPS)$$

⇨ $\mathbf{A_{trig}\,max} = -\frac{5k}{10k} \cdot (-12V) = \mathbf{6V}$

5.2 Frequency and period of the signal

- Frequency is given by the formula [6]:

$$f = \frac{1}{T}$$

⇨ $\mathbf{T} = \frac{1}{\mathrm{f}} = \frac{1}{600\mathrm{Hz}} = \mathbf{1.666\ ms}$

Now that we know the value of the T, the period, we can compute the values of the resistors *R5* and *R6*, which are equal.

We calculate them with the formula below [6]:

$$T = 4 \cdot R5 \cdot C1 \cdot \frac{R7}{R8}$$

⇨ $1.66ms = 4 \cdot R5 \cdot 50nF \cdot \frac{5k}{10k}$

⇔ $R5 = \frac{1.66 \cdot 10^{-3} \cdot 10^{9}}{100} = 0.0166 \cdot 10^{6} = 16.66k = R6$

⇨ **R5 =16.66kΩ**
R6 =16.66kΩ

- The resistor *R9* is equal to *R7*||*R8*

⇨ **R9** = $\frac{R7 \cdot R8}{R7+R8} = \frac{5k \cdot 10k}{5k+10k} = \mathbf{3.333}\boldsymbol{k}\Omega$

**From my calculations, with the given value of the frequency 600Hz, the period is 1.666ms, but on the displayed signal the period is about 1.79ms, so it is a little bit bigger.*

5.3 Adjustment of the Duty Cycle

- Chosen value: **Rpot1 = 10kΩ**

To make the adjustment of the duty cycle possible in the given interval, first it is needed to compute the value of the reference voltage [7].

Since the duty cycle needs to vary between 60% and 80% there will be 2 reference voltages. Let`s call them *V60* and *V80*.

- V60 is equal to the voltge at 60% of the way between A_{trig}min and A_{trig}max.
  - ⇨ V60 = 1.2V
- V80 is equal to the voltge at 80% of the way between A_{trig}min and A_{trig}max.
  - ⇨ V80 = 3.6V

Now we need to compute the values of the resistors *R1* and *R2*. To do that we also need the value of the current which passes through them [7].

$$I = \frac{V80 - V60}{Rpot1}$$

⇨ $\boldsymbol{I = \frac{3.6-1.2}{10k} = 0.24mA}$

$$R1 = \frac{+VPS - V80}{I}$$

⇨ **R1** $= \frac{12-3.6}{0.24m} = \mathbf{35k}\Omega$

$$R2 = \frac{V60 - (-VPS)}{I}$$

⇨ **R2** $= \frac{1.2+12}{0.24m} = \mathbf{55k}\Omega$

5.4 Adjustment of the PWM Amplitude

- Chosen value: **Rpot2 = 10kΩ**

The adjustment of the amplitude is given by the potentiometer *Rpot2* and the two resistors *R3* and *R4*.

Just like at the adjustment of the duty cycle, a reference voltage value is needed to make the amplitude variable between the required interval, [1V – 6V]. Once again we will obtain a min ref. voltage and a max ref. voltage.

Since one end of the voltage divider is connected at the output of *U4A*, and the other end is connected to ground, the maximum reference value, *Vcc*, is the voltage at the output of *U4A*. The minimum reference value, *Vee* is equal to 0, because of the ground.

⇨ **Vcc = 10.5V**
Vee = 0V

To compute the resistors *R3* and *R4* we use the following formulas [5]:

$$Vmax = Vcc\frac{Rpot2 + R4}{Rpot2 + R4 + R3} + Vee\frac{R3}{Rpot2 + R4 + R3}$$

$$Vmin = Vcc\frac{R4}{Rpot2 + R4 + R3} + Vee\frac{R4 + Rpot2}{Rpot2 + R4 + R3}$$

- In this context, **Vmax=6V** and **Vmin= 1V,** which are the values from the given amplitude interval, [1V-6V].

⇨ $6 = 10.5\frac{10+R4}{10+R4+R3}$

⇔ 6R4 + 6R3 + 60 = 105 + 10.5R4

⇔ -4.5R4 + 6R3 = 45 (1)

⇨ $1 = 10.5\frac{R4}{10+R4+R3}$

⇔10.5R4 = R3 + R4 + 10

⇔ 9.5R4 - R3 = 10 (2)

⇨ From equations (1) and (2) we get **R3 = 9.5R4 – 10**

⇨ -4.5R4-60+57R4=45

⇔ 52.5R4=105

⇔ **R4=2kΩ => R3=9kΩ**

6. Calculated and standardized values

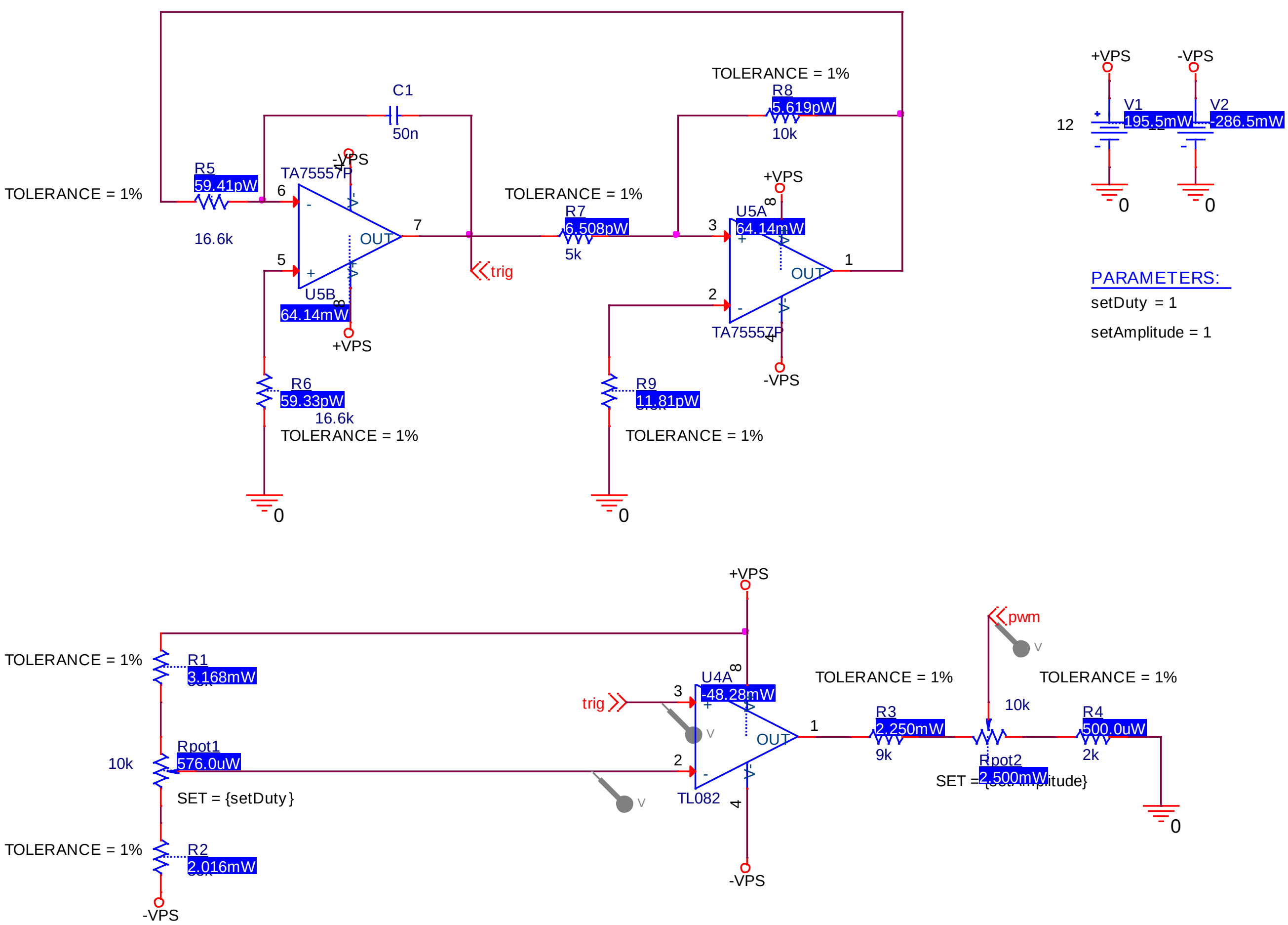
The components used in the circuit, with their calculated and standard values are listed in *Table 2*.

Component	Calculated Value	Standard Value	Measured Power	Tolerance	Component Description
R1	55kΩ	55kΩ		1%	: RES 55K OHM 1/4W 1% AXIAL
R2	35kΩ	35kΩ	2.016mW	1%	RES 35K OHM 1/8W 1% AXIAL
R3	9kΩ	9kΩ	2.25mW	1%	RES 9K OHM 7W 1% AXIAL
R4	2kΩ	2kΩ	500uW	1%	RES 2K OHM 1/4W 5% AXIAL
R5	16.66kΩ	16.6kΩ	59.41pW	1%	RES 16.6K OHM 1/4W 1% AXIAL
R6	16.66kΩ	16.6kΩ	59.33pW	1%	RES 16.6K OHM 1/4W 1% AXIAL
R7	5kΩ	5kΩ	6.508pW	1%	RES 5K OHM 15W 1% AXIAL
R8	10kΩ	10kΩ	5.619pW	1%	RES 10K OHM 1/4W 1% AXIAL
R9	3.333kΩ	3.3kΩ	11.81pW	1%	RES 3.3K OHM 1/4W 1% AXIAL
C1	50nF	0.05uF = 50nF	---------	-------	CAP CER 0.05UF 50V X7R 1206
Rpot1	10kΩ	10kΩ	576 uW	1%	POT 10K OHM 2W WIREWOUND LINEAR
Rpot2	10kΩ	10kΩ	2.5mW	1%	POT 10K OHM 2W WIREWOUND LINEAR

Table 2

*For the standard values of the components I have used the website called “*Digikey*”.[11]

- For each resistor, I measured the power on each one, by running a Bias Point simulation. The results can be seen in the figure below:



Results after using the standard values:

- **The frequency**:

The frequency calculated with the standard values is:

$$f = \frac{1}{4 \cdot R5 \cdot C1 \cdot \frac{R7}{R8}}$$

⇨ $\boldsymbol{f} = \frac{1}{4 \cdot 16.6k \cdot 50 \cdot 10^{-9} \cdot \frac{5k}{10k}} = \frac{10^4}{16.6} = \boldsymbol{602Hz}$

The **required frequency** is **600Hz,** so it can be observed that the two frequencies differ by 2Hz. The reason why this happened is because the calculated value of R5 was 16.66k and the standard value is 16.6k. Also, the standard value of resistor R5 has a ±1% Tolerance, which can cause fluctuations in values.

- **The duty cycle and the amplitude of the PWM signal**

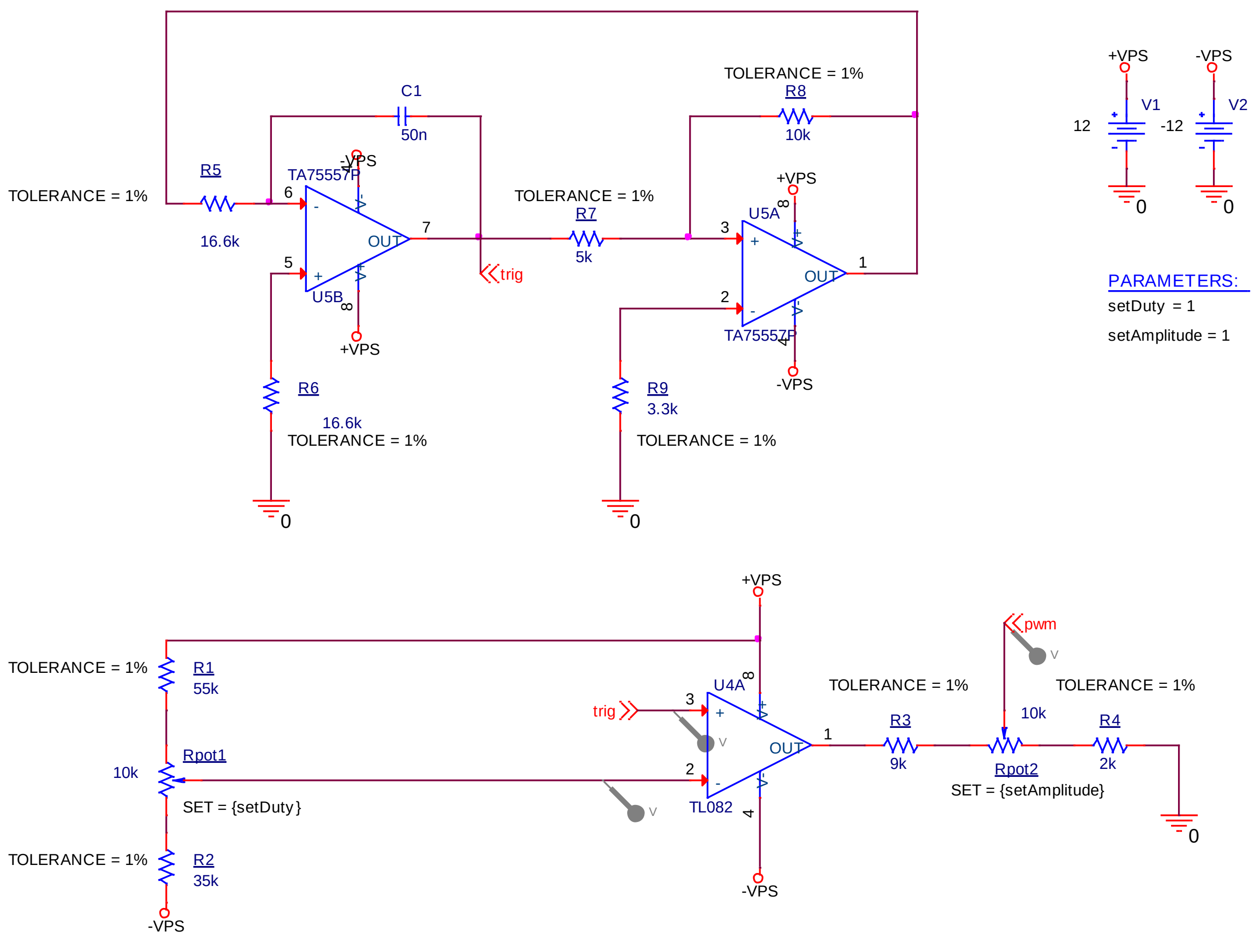
The duty cycle and the amplitude won`t present any differences because the calculated values of the components from the formulas which helped compute them are the same with the standard values, as can be seen in *Table2*.

7. Experimental simulations results

7.1 Time domain simulation

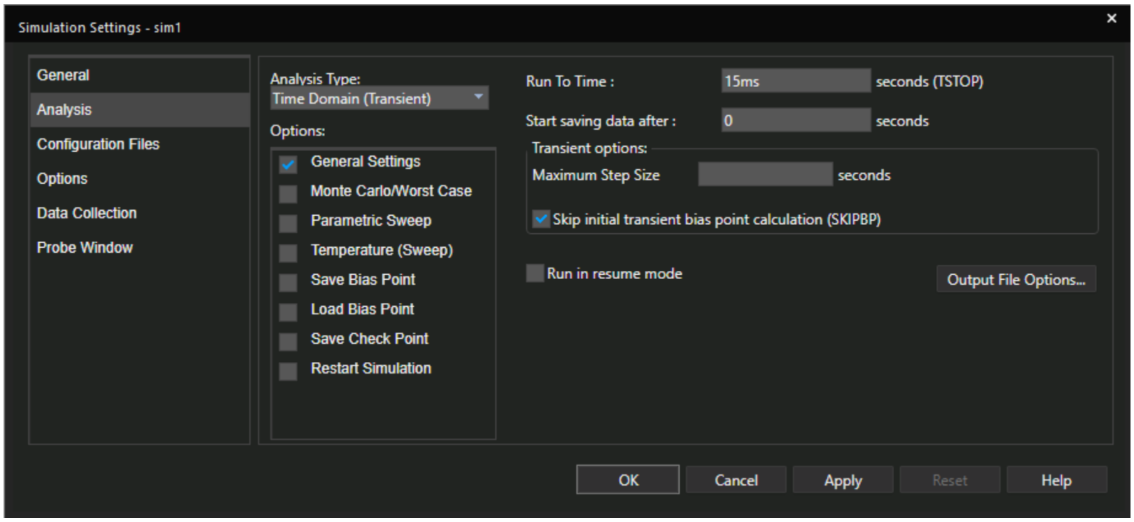
I chose to run this simulation so that I can observe how my signal varies in time.

- Schematic:



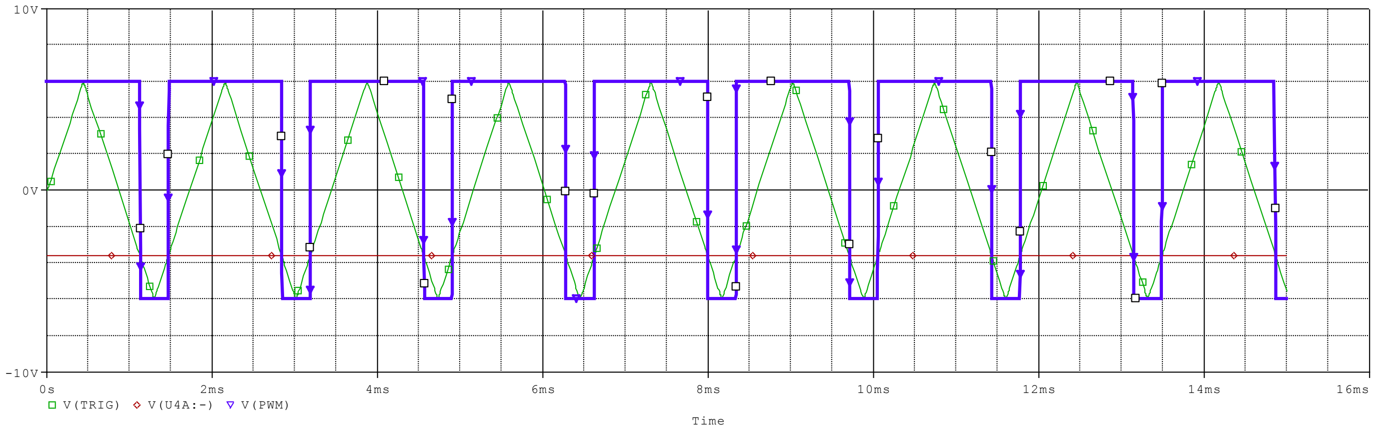
- Simulation Profile:

I chose the Run to Time parameter to be 15ms because it is enough time to see the signal clearly, and to observe how it varies in time.



- Results:

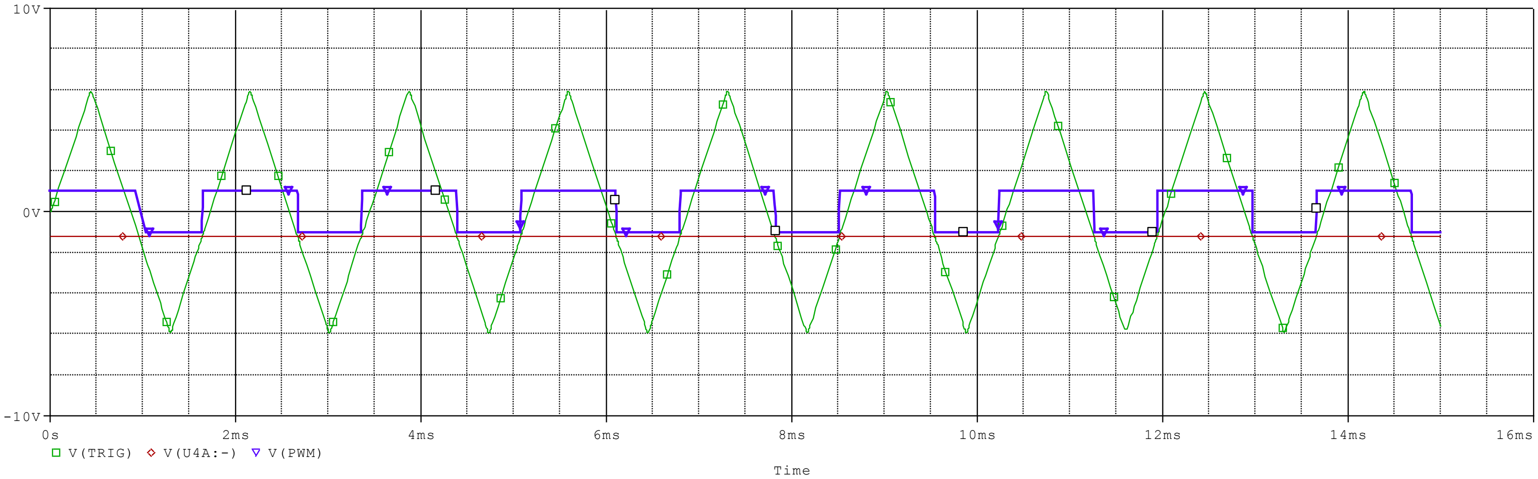
For setDuty=1 and setAmplitude=1:



From this result it can be observed that, when setDuty is equal to 1, the duty cycle is 80%, and when setAmplitude is also equal to 1 the amplitude of the PWM signal is equal to 6V.

In both of this results it can be seen that triangular signal stays at the calculated values, which are ±6 V.

For setDuty = 0 and setAmplitude = 0:



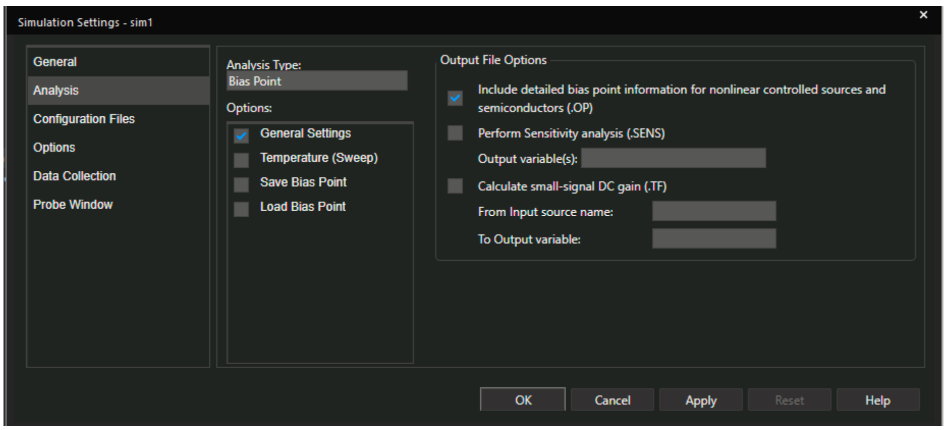
In this case, when setDuty is equal to 0 and setAmplitude is also equal to 0, the duty cycle has been adjusted to 60% and the amplitude of the PWM signal is 1V.

- In both of this results it can be seen that triangular signal stays at the calculated values, which are ±6 V.

7.2 Bias Point simulation

I chose to run this simulation so that I can determine the voltages at each node, and the currents and power through each device. In this simulation the capacitor C1 will be treated as an open-circuit.

- Simulation profile:



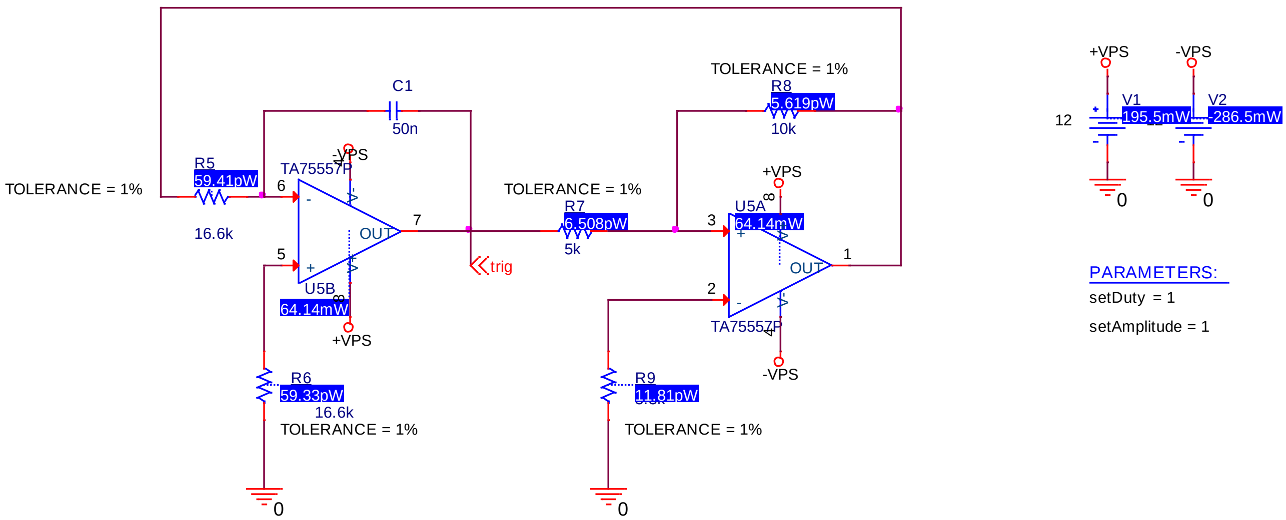
- Results:

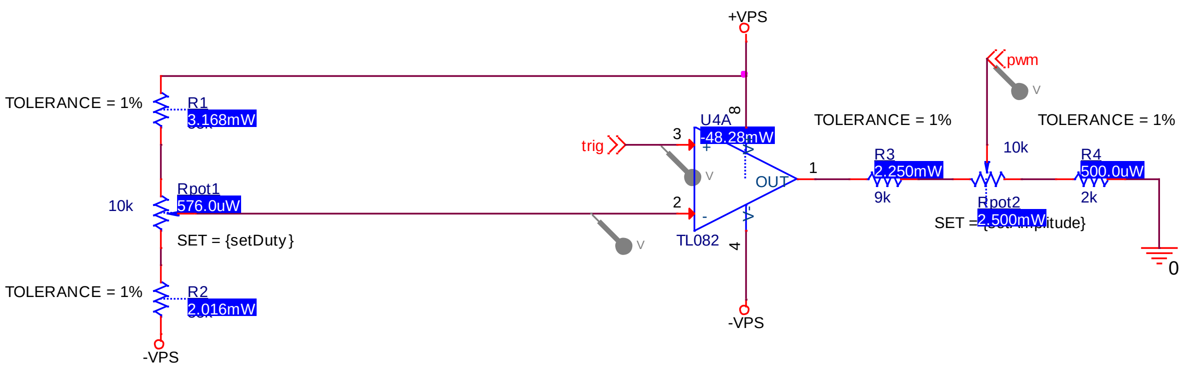
Power

Power is calculated with the formula below[15]:

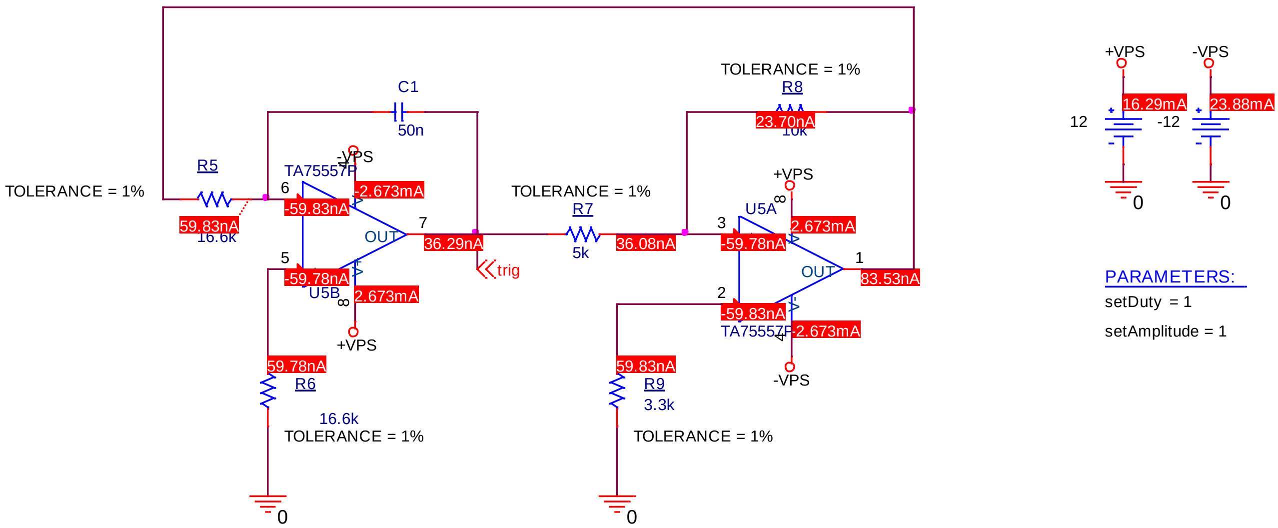
$$P = VI$$

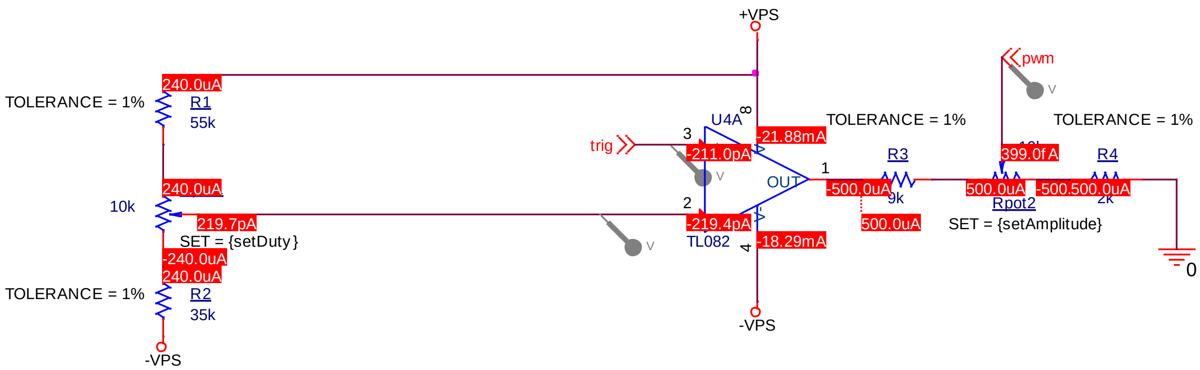
Where P is the power, V is the voltage and I is the current


TOLERANCE = 1%
R5
59.41pW
16.6k
C1
50n
-VPS
TA75557P
6
7
5
OUT
U5B
64.14mW
+VPS
trig
R6
59.33pW
16.6k
TOLERANCE = 1%
TOLERANCE = 1%
R7
6.508pW
5k
TOLERANCE = 1%
R8
5.619pW
10k
+VPS
U5A
64.14mW
3
2
1
OUT
TA75557P
-VPS
R9
11.81pW
TOLERANCE = 1%
0
0
+VPS
-VPS
V1
195.5mW
V2
-286.5mW
12
0
0
PARAMETERS:
setDuty = 1
setAmplitude = 1


TOLERANCE = 1%
R1
3.168mW
Rpot1
576.0uW
10k
SET = {setDuty}
TOLERANCE = 1%
R2
2.016mW
-VPS
+VPS
U4A
-48.28mW
trig
3
2
1
OUT
TL082
-VPS
TOLERANCE = 1%
R3
2.250mW
9k
pwm
10k
Rpot2
2.500mW
TOLERANCE = 1%
R4
500.0uW
2k
0

<u>*Current:*</u>


TOLERANCE = 1%
R5
16.6k
59.83nA
C1
50n
-VPS
TA75557P
-2.673mA
-59.83nA
OUT
36.29nA
trig
-59.78nA
U5B
2.673mA
+VPS
59.78nA
R6
16.6k
TOLERANCE = 1%
R7
5k
36.08nA
R8
10k
23.70nA
U5A
2.673mA
-59.78nA
83.53nA
-59.83nA
TA75557P
-2.673mA
-VPS
59.83nA
R9
3.3k
+VPS
12
-12
16.29mA
23.88mA
PARAMETERS:
setDuty = 1
setAmplitude = 1


+VPS
pwm
TOLERANCE = 1%
240.0uA
R1
55k
10k
240.0uA
219.7pA
SET = {setDuty}
-240.0uA
240.0uA
R2
35k
-VPS
trig
U4A
-21.88mA
-211.0pA
OUT
-500.0uA
R3
9k
500.0uA
-219.4pA
TL082
-18.29mA
399.0fA
500.0uA
-500.500.0uA
Rpot2
R4
2k
SET = {setAmplitude}

Bogdan Andreea Laura
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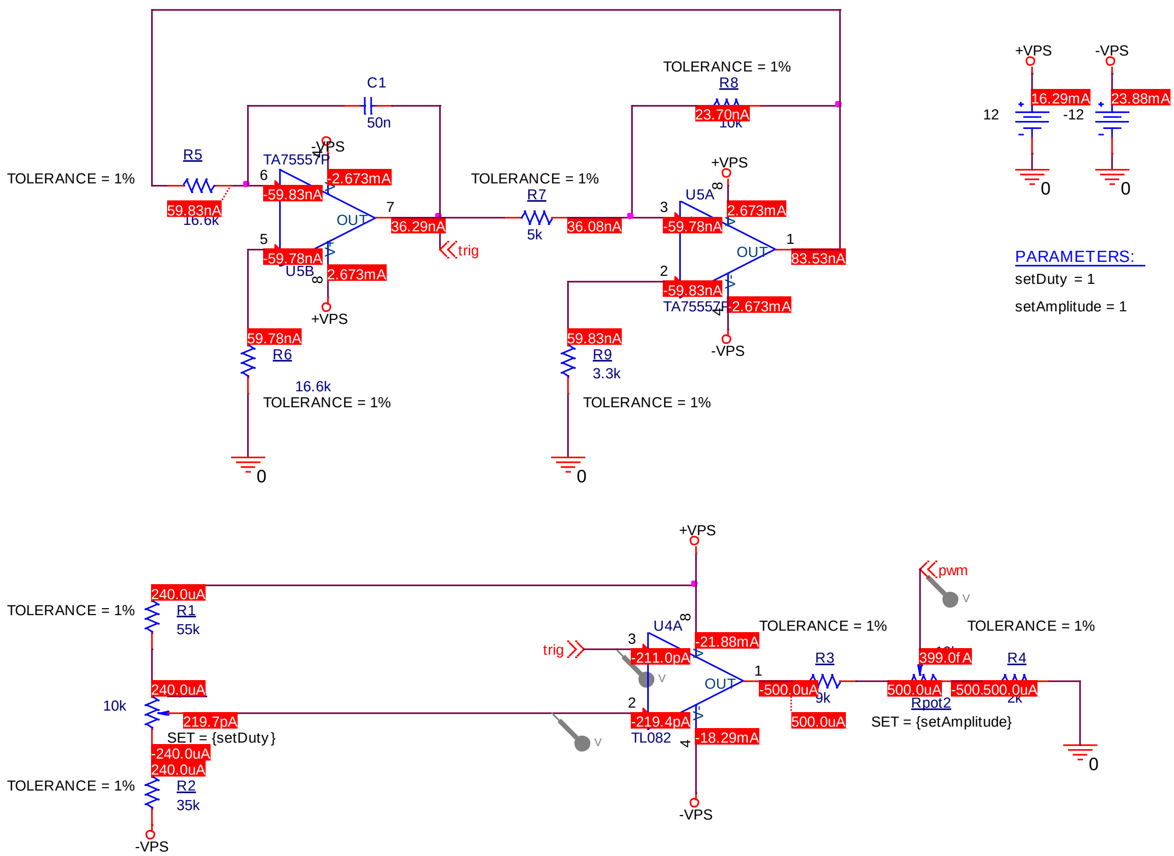
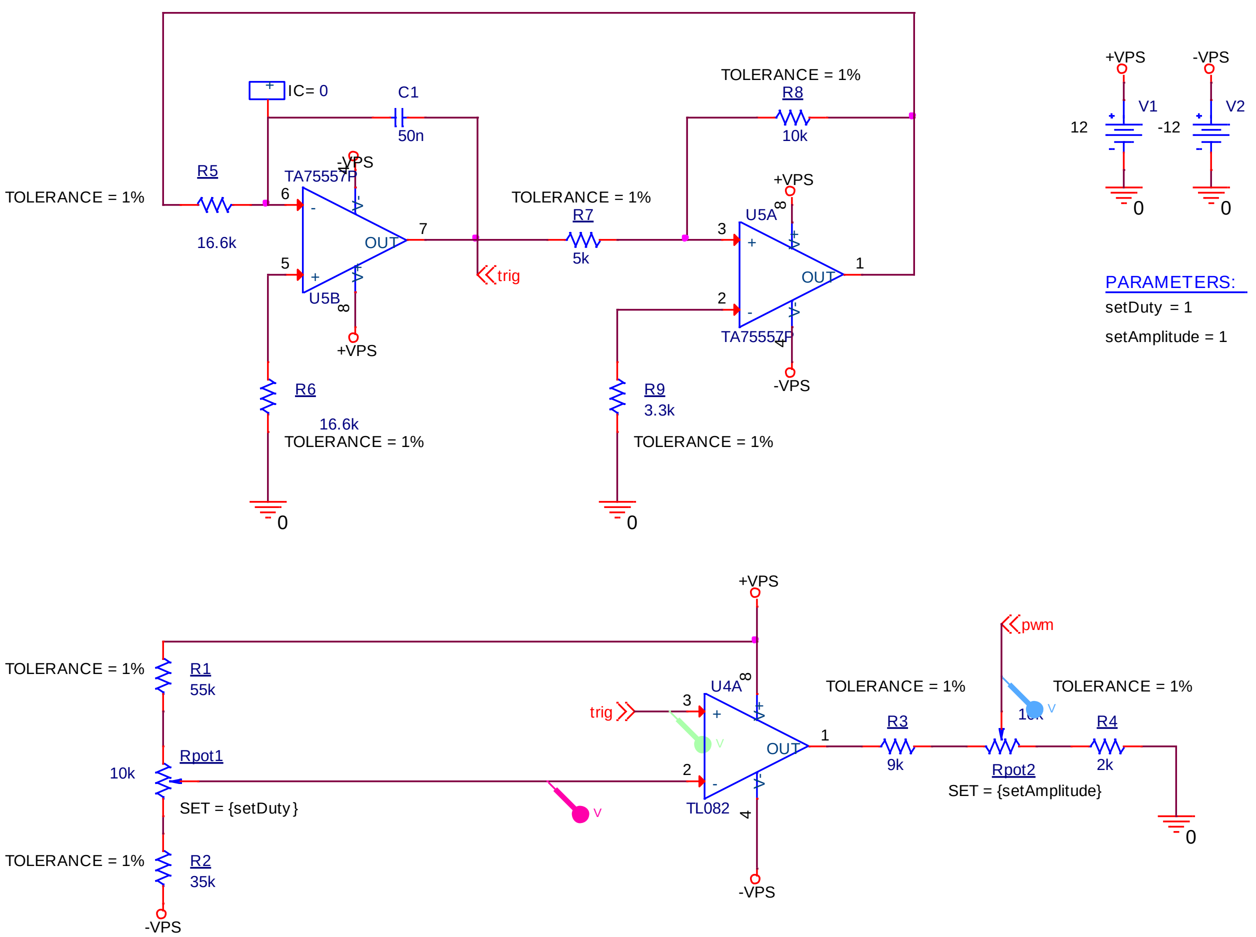
Eng

Voltage



7.3 Parametric Sweep

Schematic:



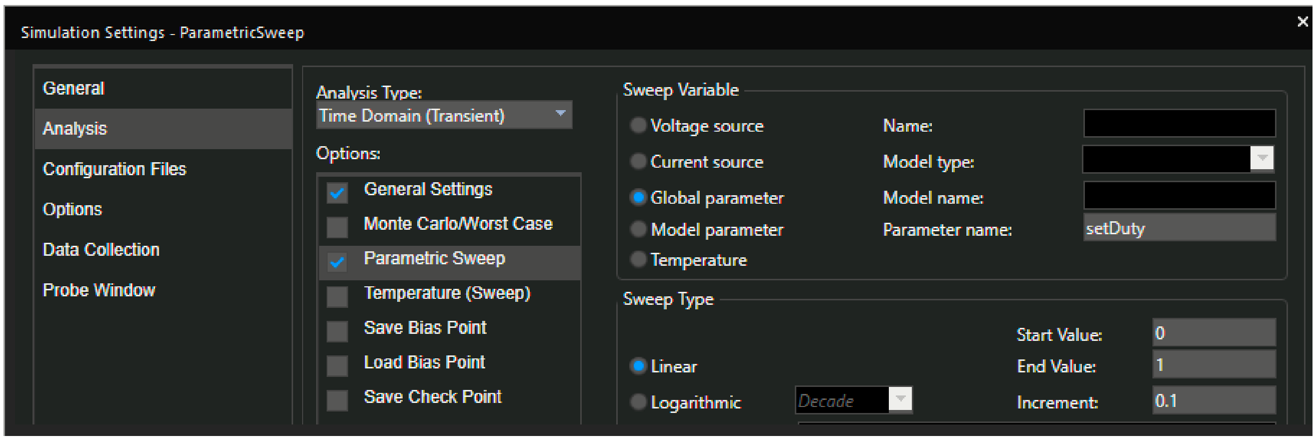
I added IC=0 so that my signal can start from 0 on the axis of time.

I chose to do this simulation so that I can see how the components which have variable values, the potentiometers Rpot1 and Rpot2 vary. Rpot1 (setDuty) varies the duty cycle between [60%-80%] and Rpot2 (setAmplitude) varies the amplitude of the PWM cycle between [1-6V].

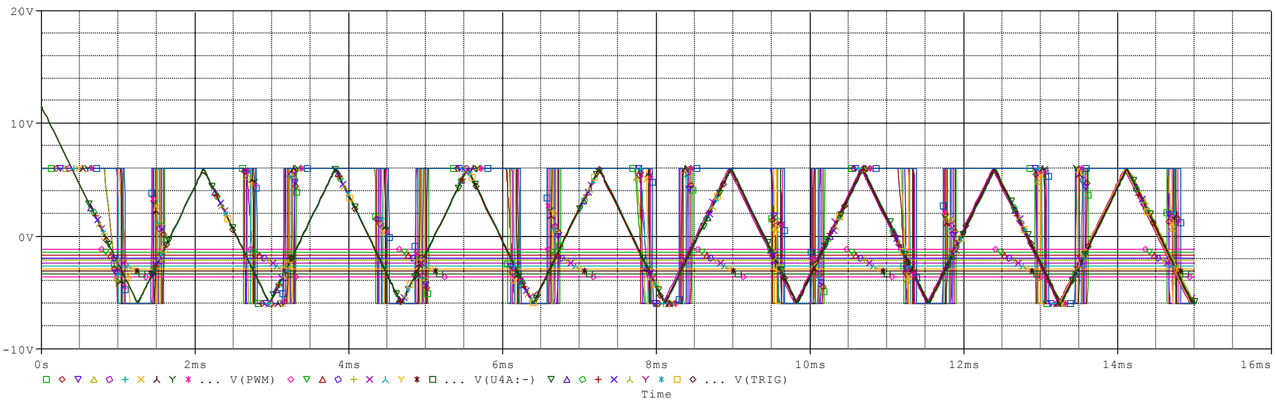
- For the duty cycle:

Simulation profile:

In the value list I chose the values 0 and 1 so that I can see how the value of the Duty Cycle varies for the minimum value of the potentiometer and for the maximum value, and the increment of 0.1 so that the duty cycle for all the values of the potentiometer is displayed.



Results:

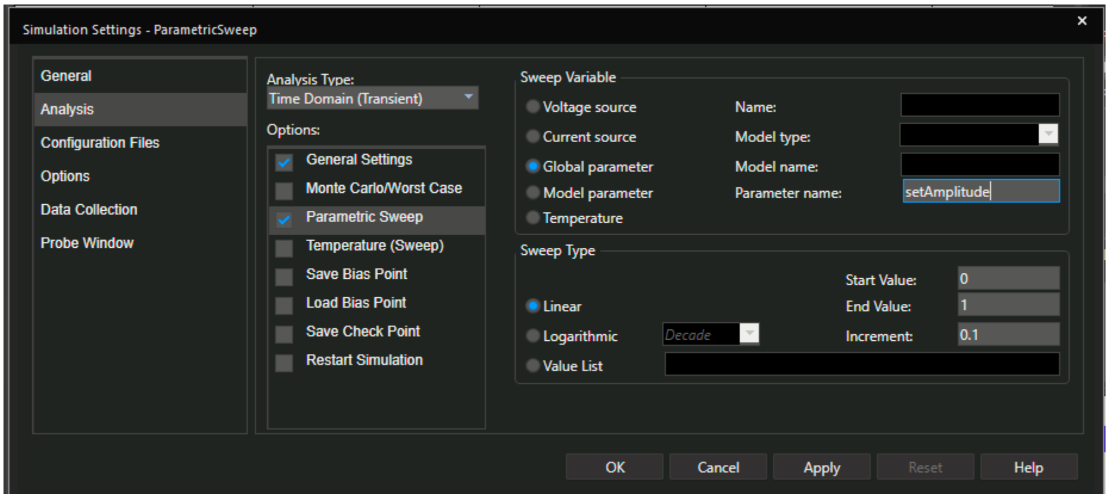


This result shows us how the duty cycle varies between 60% and 80% for all the values of the potentiometer in time. The amplitude of the triangle signal staies at 6 V.

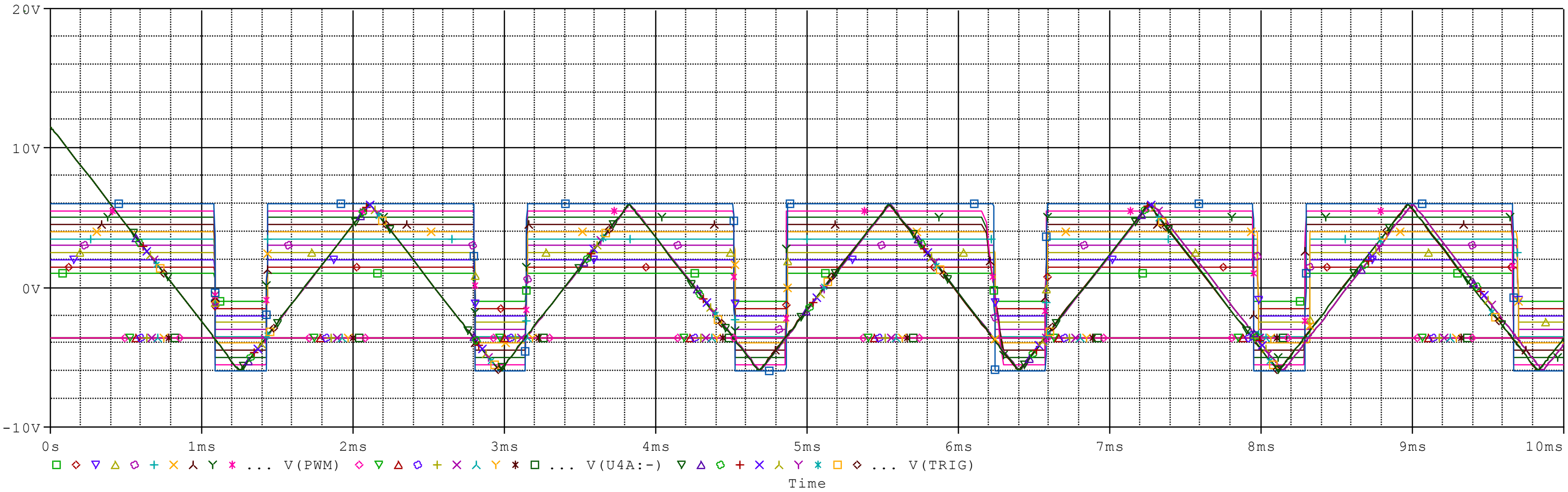
- For the amplitude:

Simulation Profile:

For the simulation profile for the amplitude I chose the same values as for the simulation I did for the duty cycle, since I also needed to see hoe the amplitude of the pwm signal varie for all the values of the potentiometer. Start value 0, end value 1 and increment 0.1. I sewpt this for the period of time of 10ms, the reason behing this being so the I can see my signal better.



Results:



From this simulation we can observe how the amplitude for the pwm signal varies for all the values of the potentiometer. The maximum is 6V and the miumum is 1, just like it was required.

8. Bill of Materials

```
PWM Generator  Revised: Friday, May 22, 2020
Bogdan Andreea Laura          Revision:

Bill Of Materials            May 22,2020      19:44:18  Page1

Item    Quantity    Reference   Part
______________________________________________

1   1   C1  50n DigiKey AVX Corporation CAP CER 0.05UF 50V X7R 1206
2   1   Rpot1   10k DigiKey Bourns Inc. POT 10K OHM 2W WIREWOUND LINEAR
3   1   Rpot2   10k DigiKey Bourns Inc  POT 10K OHM 2W WIREWOUND LINEAR
4   1   R1  55k DigiKey Vishay Dale RES 55K OHM 1/4W 1% AXIAL
5   1   R2  35k DigiKey Vishay Dale RES 35K OHM 1/8W 1% AXIAL
6   1   R3  9k  DigiKey Vishay Dale RES 9K OHM 1/4W 1% AXIAL
7   1   R4  2k  DigiKey Stackpole Electronics Inc   RES 2K OHM 1/4W 1% AXIAL
8   2   R5,R6   16.6k   DigiKey Vishay Dale RES 16.6K OHM 1/4W 1% AXIAL
9   1   R7  5k  DigiKey Vishay Dale RES 5K OHM 1/4W 1% AXIAL
10  1   R8  10k DigiKey Yageo   RES 10K OHM 1/4W 1% AXIAL
11  1   R9  3.3k    DigiKey Stackpole Electronics Inc   RES 3.3K OHM 1/4W 1% AXIAL
12  1   U4  TL082   DigiKey Texas Instruments
13  1   U5  TA75557P    UTsource    Toshiba
```

9. Components Datasheets

- *R1:*

  - ⇨ Calculated value : 55k;
  - ⇨ Standard value: 55k;
  - ⇨ Measured Power: 3.168 mW;
  - ⇨ Tolerance: ±1%.
  - ⇨ Seller: Digikey[11];
  - ⇨ Manufacturer: Vishay Dale
  - ⇨ Description: RES 55K OHM 1/4W 1% AXIAL
  - ⇨ Part number: RN60C5502FB14-ND

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CMF (Military RN and RL)
Vishay Dale

Metal Film Resistors, Axial, Military, MIL-R-10509 Qualified, Precision, Type RN and MIL-PRF-22684 Qualified, Type RL

FEATURES

- Very low noise (-40 dB)
- Very low voltage coefficient (5 ppm/V)
- Controlled temperature coefficient
- Flame retardant epoxy coating
- Commercial alternatives to military styles are available with higher power ratings. See CMF Industrial data sheet: (www.vishay.com/doc?31018)

STANDARD ELECTRICAL SPECIFICATIONS

GLOBAL MODEL	MIL STYLE	MIL SPEC. SHEET	POWER RATING $P_{70\,°C}$ W	POWER RATING $P_{125\,°C}$ W	MAX. WORKING VOLTAGE (1) V	RESISTANCE RANGE Ω MIL-R-10509 ± 100 ppm/°C (D)	RESISTANCE RANGE Ω MIL-R-10509 ± 50 ppm/°C (C)	RESISTANCE RANGE Ω MIL-R-10509 ± 25 ppm/°C (E)	RESISTANCE RANGE Ω MIL-PRF-22684	TOL. (3) ± %	DIELECTRIC STRENGTH V_{AC}
CMF50	RN50	08	-	0.05	200	-	10 to 100K	10 to 100K	-	0.1, 0.25, 0.5, 1	450
CMF55	RN55	07	0.125	0.10	200	10 to 301K	49.9 to 100K	49.9 to 100K	-	0.1, 0.25, 0.5, 1	450
CMF60	RN60	01	0.25	0.125	300	10 to 1M	49.9 to 499K	49.9 to 499K	-	0.1, 0.25, 0.5, 1	500
CMF65	RN65	02	0.50	0.25	350	10 to 2M	49.9 to 1M	49.9 to 1M	-	0.1, 0.25, 0.5, 1	900
CMF70	RN70	03	0.75 (2)	0.50	500	10 to 2.49M	24.9 to 1M	24.9 to 1M	-	0.1, 0.25, 0.5, 1	900
CMF07	RL07	01	0.25	-	250	-	-	-	51 to 150K	2, 5	450
CMF20	RL20	02	0.50	-	350	-	-	-	4.3 to 470K	2, 5	700

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CMF (Military RN and RL)

Vishay Dale

GLOBAL PART NUMBER INFORMATION

New Global Part Numbering: RN60D3483FR36 (preferred part numbering format)

R	N	6	0	D	3	4	8	3	F	R	3	6			

MIL STYLE	CHARACTERISTIC	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING	SPECIAL
RN50 **RN55** **RN60** **RN65** **RN70**	**E** = 25 ppm **C** = 50 ppm **D** = 100 ppm	3 digit significant figure, followed by a multiplier Use "R" for values < 100 Ω **10R0** = 10 Ω **2152** = 21.5 kΩ **2494** = 2.49 MΩ	**B** = ± 0.1 % **C** = ± 0.25 % **D** = ± 0.5 % **F** = ± 1 %	**B14** = tin/lead, bulk **BSL** = tin/lead, bulk, single lot date code **R36** = tin/lead, T/R (full) **RE6** = tin/lead, T/R (1000 pieces) **RSL** = tin/lead, T/R, single lot date code	Blank = standard (Dash number) **88** = hot solder dip **143** = non-magnetic

Historical Part Number example: RN60D3483F (will continue to be accepted)

RN60	D	3483	F	R36
MIL STYLE	CHARACTERISTIC	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING

New Global Part Numbering: RL07S471JR36 (preferred part numbering format)

R	L	0	7	S	4	7	1	J	R	3	6			

MIL STYLE	LEAD MATERIAL	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING	SPECIAL
RL07 **RL20**	**S** = solderable	2 digit significant figure, followed by a multiplier Use "R" for values < 10 Ω **4R3** = 4.3 Ω **202** = 2.0 kΩ **474** = 470 kΩ	**G** = ± 2 % **J** = ± 5 %	**B14** = tin/lead, bulk **BSL** = tin/lead, bulk, single lot date code **R36** = tin/lead, T/R (full) **RE6** = tin/lead, T/R (1000 pieces) **RSL** = tin/lead, T/R, single lot date code	Blank = standard (Dash number) **88** = hot solder dip **143** = non-magnetic

Historical Part Number example: RL07S471J (will continue to be accepted)

RL07	S	471	J	R36
MIL STYLE	LEAD MATERIAL	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING

- *R2:*

  - ⇨ Calculated value : 35k;
  - ⇨ Standard value: 35k;
  - ⇨ Measured Power: 2.016 mW;
  - ⇨ Tolerance: 1%.
  - ⇨ Seller: Digikey[11];
  - ⇨ Manufacturer: Vishay Dale
  - ⇨ Description: RES 35K OHM 1/8W 1% AXIAL
  - ⇨ Part number: RN55C3502FB14-ND

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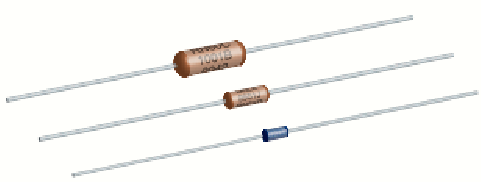
CMF (Military RN and RL)

Vishay Dale

Metal Film Resistors, Axial, Military, MIL-R-10509 Qualified, Precision, Type RN and MIL-PRF-22684 Qualified, Type RL



FEATURES

- Very low noise (-40 dB)
- Very low voltage coefficient (5 ppm/V)
- Controlled temperature coefficient
- Flame retardant epoxy coating
- Commercial alternatives to military styles are available with higher power ratings. See CMF Industrial data sheet: (www.vishay.com/doc?31018)

STANDARD ELECTRICAL SPECIFICATIONS

GLOBAL MODEL	MIL STYLE	MIL SPEC. SHEET	POWER RATING $P_{70\,°C}$ W	POWER RATING $P_{125\,°C}$ W	MAX. WORKING VOLTAGE (1) V	RESISTANCE RANGE Ω MIL-R-10509 ± 100 ppm/°C (D)	RESISTANCE RANGE Ω MIL-R-10509 ± 50 ppm/°C (C)	RESISTANCE RANGE Ω MIL-R-10509 ± 25 ppm/°C (E)	RESISTANCE RANGE Ω MIL-PRF-22684	TOL. (3) ± %	DIELECTRIC STRENGTH V_{AC}
CMF50	RN50	08	-	0.05	200	-	10 to 100K	10 to 100K	-	0.1, 0.25, 0.5, 1	450
CMF55	RN55	07	0.125	0.10	200	10 to 301K	49.9 to 100K	49.9 to 100K	-	0.1, 0.25, 0.5, 1	450
CMF60	RN60	01	0.25	0.125	300	10 to 1M	49.9 to 499K	49.9 to 499K	-	0.1, 0.25, 0.5, 1	500
CMF65	RN65	02	0.50	0.25	350	10 to 2M	49.9 to 1M	49.9 to 1M	-	0.1, 0.25, 0.5, 1	900
CMF70	RN70	03	0.75 (2)	0.50	500	10 to 2.49M	24.9 to 1M	24.9 to 1M	-	0.1, 0.25, 0.5, 1	900
CMF07	RL07	01	0.25	-	250	-	-	-	51 to 150K	2, 5	450
CMF20	RL20	02	0.50	-	350	-	-	-	4.3 to 470K	2, 5	700

VISHAY. www.vishay.com

CMF (Military RN and RL)

Vishay Dale

GLOBAL PART NUMBER INFORMATION

New Global Part Numbering: RN60D3483FR36 (preferred part numbering format)

R	N	6	0	D	3	4	8	3	F	R	3	6			

MIL STYLE	CHARACTERISTIC	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING	SPECIAL
RN50 **RN55** **RN60** **RN65** **RN70**	**E** = 25 ppm **C** = 50 ppm **D** = 100 ppm	3 digit significant figure, followed by a multiplier Use "R" for values < 100 Ω **10R0** = 10 Ω **2152** = 21.5 kΩ **2494** = 2.49 MΩ	**B** = ± 0.1 % **C** = ± 0.25 % **D** = ± 0.5 % **F** = ± 1 %	**B14** = tin/lead, bulk **BSL** = tin/lead, bulk, single lot date code **R36** = tin/lead, T/R (full) **RE6** = tin/lead, T/R (1000 pieces) **RSL** = tin/lead, T/R, single lot date code	Blank = standard (Dash number) **88** = hot solder dip **143** = non-magnetic

Historical Part Number example: RN60D3483F (will continue to be accepted)

RN60	D	3483	F	R36
MIL STYLE	CHARACTERISTIC	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING

New Global Part Numbering: RL07S471JR36 (preferred part numbering format)

R	L	0	7	S	4	7	1	J	R	3	6			

MIL STYLE	LEAD MATERIAL	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING	SPECIAL
RL07 **RL20**	**S** = solderable	2 digit significant figure, followed by a multiplier Use "R" for values < 10 Ω **4R3** = 4.3 Ω **202** = 2.0 kΩ **474** = 470 kΩ	**G** = ± 2 % **J** = ± 5 %	**B14** = tin/lead, bulk **BSL** = tin/lead, bulk, single lot date code **R36** = tin/lead, T/R (full) **RE6** = tin/lead, T/R (1000 pieces) **RSL** = tin/lead, T/R, single lot date code	Blank = standard (Dash number) **88** = hot solder dip **143** = non-magnetic

Historical Part Number example: RL07S471J (will continue to be accepted)

RL07	S	471	J	R36
MIL STYLE	LEAD MATERIAL	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING

- *R3:*

  - ⇨ Calculated value : 9k;
  - ⇨ Standard value: 9k;
  - ⇨ Measured Power: 2.250 mW;
  - ⇨ Tolerance: 1%.
  - ⇨ Seller: Digikey[11];
  - ⇨ Manufacturer: Vishay Dale
  - ⇨ Description: RES 9K OHM 1/4W 1% AXIAL
  - ⇨ Part number: RN60D9001FB14-ND

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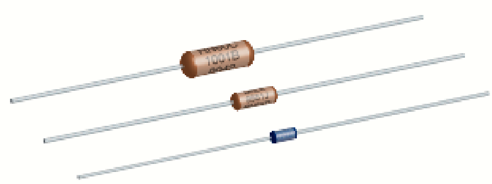
CMF (Military RN and RL)
Vishay Dale

Metal Film Resistors, Axial, Military, MIL-R-10509 Qualified, Precision, Type RN and MIL-PRF-22684 Qualified, Type RL

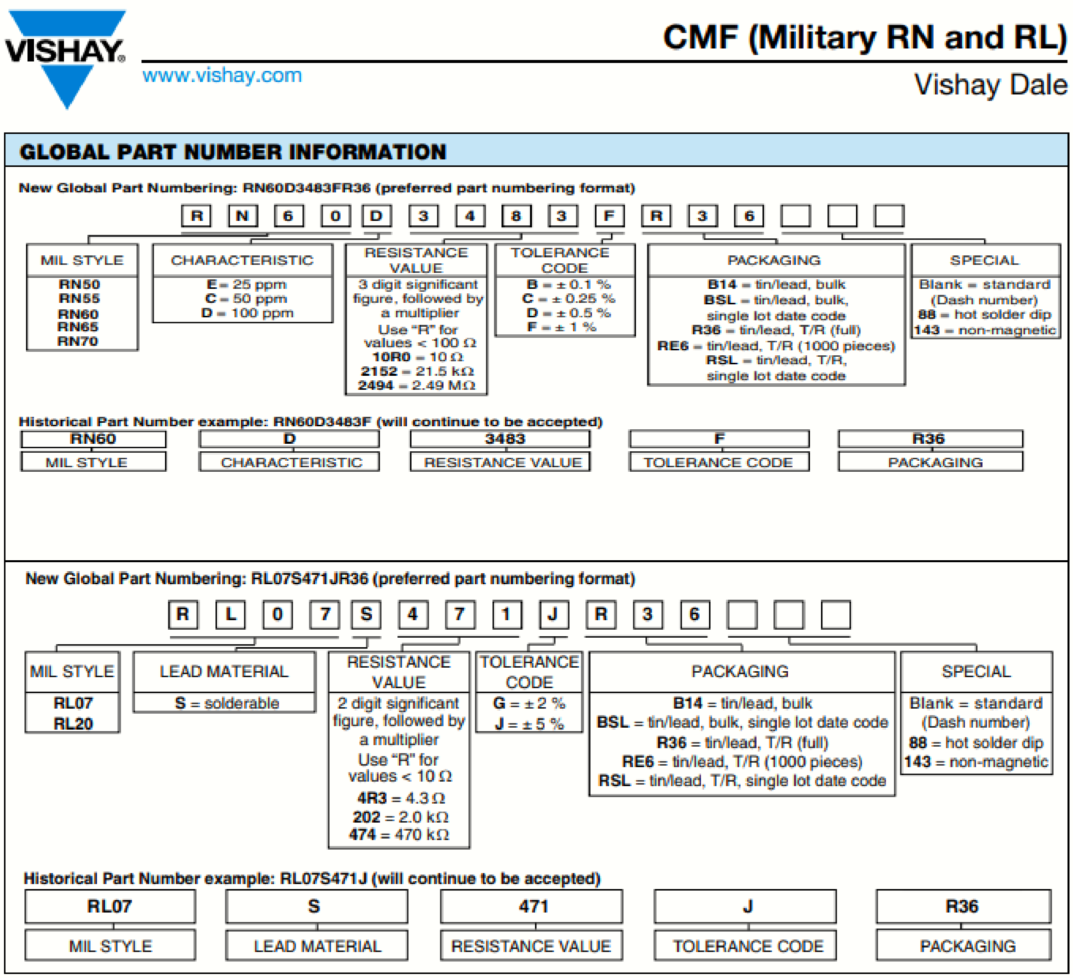


FEATURES
- Very low noise (-40 dB)
- Very low voltage coefficient (5 ppm/V)
- Controlled temperature coefficient
- Flame retardant epoxy coating
- Commercial alternatives to military styles are available with higher power ratings. See CMF Industrial data sheet: (www.vishay.com/doc?31018)

STANDARD ELECTRICAL SPECIFICATIONS

GLOBAL MODEL	MIL STYLE	MIL SPEC. SHEET	POWER RATING $P_{70\,°C}$ W	POWER RATING $P_{125\,°C}$ W	MAX. WORKING VOLTAGE (1) V	RESISTANCE RANGE Ω MIL-R-10509 ± 100 ppm/°C (D)	RESISTANCE RANGE Ω MIL-R-10509 ± 50 ppm/°C (C)	RESISTANCE RANGE Ω MIL-R-10509 ± 25 ppm/°C (E)	RESISTANCE RANGE Ω MIL-PRF-22684	TOL. (3) ± %	DIELECTRIC STRENGTH V_{AC}
CMF50	RN50	08	-	0.05	200	-	10 to 100K	10 to 100K	-	0.1, 0.25, 0.5, 1	450
CMF55	RN55	07	0.125	0.10	200	10 to 301K	49.9 to 100K	49.9 to 100K	-	0.1, 0.25, 0.5, 1	450
CMF60	RN60	01	0.25	0.125	300	10 to 1M	49.9 to 499K	49.9 to 499K	-	0.1, 0.25, 0.5, 1	500
CMF65	RN65	02	0.50	0.25	350	10 to 2M	49.9 to 1M	49.9 to 1M	-	0.1, 0.25, 0.5, 1	900
CMF70	RN70	03	0.75 (2)	0.50	500	10 to 2.49M	24.9 to 1M	24.9 to 1M	-	0.1, 0.25, 0.5, 1	900
CMF07	RL07	01	0.25	-	250	-	-	-	51 to 150K	2, 5	450
CMF20	RL20	02	0.50	-	350	-	-	-	4.3 to 470K	2, 5	700

Notes



CMF (Military RN and RL)

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Vishay Dale

GLOBAL PART NUMBER INFORMATION

New Global Part Numbering: RN60D3483FR36 (preferred part numbering format)

R N 6 0 D 3 4 8 3 F R 3 6

MIL STYLE	CHARACTERISTIC	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING	SPECIAL
RN50 **RN55** **RN60** **RN65** **RN70**	**E** = 25 ppm **C** = 50 ppm **D** = 100 ppm	3 digit significant figure, followed by a multiplier Use "R" for values < 100 Ω **10R0** = 10 Ω **2152** = 21.5 kΩ **2494** = 2.49 MΩ	**B** = ± 0.1 % **C** = ± 0.25 % **D** = ± 0.5 % **F** = ± 1 %	**B14** = tin/lead, bulk **BSL** = tin/lead, bulk, single lot date code **R36** = tin/lead, T/R (full) **RE6** = tin/lead, T/R (1000 pieces) **RSL** = tin/lead, T/R, single lot date code	Blank = standard (Dash number) **88** = hot solder dip **143** = non-magnetic

Historical Part Number example: RN60D3483F (will continue to be accepted)

RN60	D	3483	F	R36
MIL STYLE	CHARACTERISTIC	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING

New Global Part Numbering: RL07S471JR36 (preferred part numbering format)

R L 0 7 S 4 7 1 J R 3 6

MIL STYLE	LEAD MATERIAL	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING	SPECIAL
RL07 **RL20**	**S** = solderable	2 digit significant figure, followed by a multiplier Use "R" for values < 10 Ω **4R3** = 4.3 Ω **202** = 2.0 kΩ **474** = 470 kΩ	**G** = ± 2 % **J** = ± 5 %	**B14** = tin/lead, bulk **BSL** = tin/lead, bulk, single lot date code **R36** = tin/lead, T/R (full) **RE6** = tin/lead, T/R (1000 pieces) **RSL** = tin/lead, T/R, single lot date code	Blank = standard (Dash number) **88** = hot solder dip **143** = non-magnetic

Historical Part Number example: RL07S471J (will continue to be accepted)

RL07	S	471	J	R36
MIL STYLE	LEAD MATERIAL	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING

- *R4*:
  - ⇨ Calculated value : 2k;
  - ⇨ Standard value: 2k;
  - ⇨ Measured Power: 500 uW;
  - ⇨ Tolerance: 1%.
  - ⇨ Seller: Digikey[11];
  - ⇨ Manufacturer: Stackpole Electronics Inc
  - ⇨ Description: RES 2K OHM 1/4W 1% AXIAL
  - ⇨ Seller Part number: S2KCATR-ND
  - ⇨ Manufacturer Part Number: RNMF14FTC2K00

RNF / RNMF Series
General Purpose Metal Film Resistor

Stackpole Electronics, Inc.
Resistive Product Solutions

Features:

- Precision metal film
- Superior electrical, TCR performances
- Flame-retardant coatings are standard
- Panasert available (selected sizes: contact factory)
- RNMF (mini) an ideal choice where size constraints apply
- RNF 5% replaces MP series
- Lower or higher resistance values may be possible (contact factory)
- RoHS compliant, lead free and halogen free

Electrical Specifications

Type / Code	Mil Ref	Power Rating (W)	Maximum Working Voltage	Maximum Overload Voltage	TCR	Ohmic Range (Ω) and Tolerance						
						0.05%	0.1%	0.25%	0.5%	1%	2%	5%
RNF18	RN 50	0.125	200	400	± 10 ppm/°C ± 25 ppm/°C ± 50 ppm/°C ± 100 ppm/°C	100 - 100 K	100 - 100 K 51.1 - 100 K	100 - 100 K	100 - 100 K 30.1 - 499 K 10 - 1 M	100 - 100 K 49.9 - 499 K 1 - 1M 1 - 10 M	- 1 - 22 M	
RNMF14	-	0.25	200	400	± 25 ppm/°C ± 50 ppm/°C ± 100 ppm/°C	-	100 - 100 K		30.1 - 499 K 10 - 1 M	30.1 - 499 K 1 - 1 M 1 - 2.15 M	- 1 - 2.2 M	
RNF14	RN 55	0.25	250	500	± 10 ppm/°C ± 25 ppm/°C ± 50 ppm/°C ± 100 ppm/°C	100 - 100 K	100 - 100 K 1 - 2.2 M	-		10 - 1 M 1 - 5.11 M 1 - 10 M	- 5.6 - 10 M	- 1.1 M - 10 M 1 - 10 M
RNMF12	RL 07	0.5	350	600	± 25 ppm/°C ± 50 ppm/°C ± 100 ppm/°C	-	30.1 - 294 K 30.1 - 1 M		49.9 - 1 M 10 - 1 M	1 - 1M 1 - 10 M	- 1 - 10 M	
RNF12	RN 60	0.5	350	700	± 25 ppm/°C ± 50 ppm/°C ± 100 ppm/°C	100 - 100 K			49.9 - 499 K 10 - 1 M	1 - 4.99 M 1 - 10 M	- 1 - 10 M	
RNF1	RN 65	1	350	700	± 25 ppm/°C ± 50 ppm/°C ± 100 ppm/°C	-			- 10 - 1 M	10 - 470 K 1 - 1 M	-	- 10 - 470 K 1 - 1 M
RNF2	-	2	350	800	± 25 ppm/°C ± 50 ppm/°C ± 100 ppm/°C	-				- 10 - 1 M	-	- 10 - 1 M

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Group 2023
Eng

- *R5:*

  ⇨ Calculated value : 16.66k;
  ⇨ Standard value: 16.6k;
  ⇨ Measured Power: 59.41pW;
  ⇨ Tolerance: 1%.
  ⇨ Seller: Digikey[11];
  ⇨ Manufacturer: Vishay Dale
  ⇨ Description: RES 16.6K OHM 1/4W 1% AXIAL
  ⇨ Seller Part number: CMF5016K600FKBF-ND
  ⇨ Manufacturer Part Number: CMF5016K600FKBF

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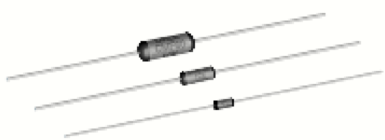
CMF Industrial
Vishay Dale

Metal Film Resistors, Axial, Industrial, Precision



FEATURES
- Small size - conformal coated
- Flame retardant epoxy coating
- Controlled temperature coefficient
- Excellent high frequency characteristics
- Exceptionally low noise; typically 0.10 μV/V
- Low voltage coefficient to ± 5 ppm/V
- Special tolerance and or TC matching available on request
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

RoHS*

Note
* This datasheet provides information about parts that are RoHS-compliant and / or parts that are non-RoHS-compliant. For example, parts with lead (Pb) terminations are not RoHS-compliant. Please see the information / tables in this datasheet for details.

Vishay Dale Model CMF is also available as Military Qualified Styles RN and RL. See Vishay Dale's CMF (Military RN and RL) datasheet (www.vishay.com/doc?31027) for the MIL-SPEC ratings / attributes. (Except for marking, the Industrial and Military versions are exactly the same).

STANDARD ELECTRICAL SPECIFICATIONS

GLOBAL MODEL	HISTORICAL MODEL	MAXIMUM WORKING VOLTAGE (1) V	POWER RATING $P_{70\,°C}$ (2) W	POWER RATING $P_{125\,°C}$ (2) W	RESISTANCE RANGE Ω	TOLERANCE ± %	TEMPERATURE COEFFICIENT ± ppm/°C
CMF50	CMF-50	200	0.25	0.125	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5, 1, 2, 5	50
					10 to 2.5M	1, 2, 5	100
					10 to 22M	1, 2, 5	150, 200
CMF55	CMF-55	250	0.5	0.25	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5	50
					10 to 5M	1, 2, 5	50
					1 to 22.1M	1, 2, 5	100
					0.5 to 50M	1, 2, 5	150
					0.5 to 50M	1	200
					0.1 to 50M	2, 5	200
CMF60	CMF-60	500	1	0.5	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5	50
					10 to 10M	1, 2, 5	50
					1 to 10M	1, 2, 5	100
					0.5 to 10M	1, 2, 5	150
					0.5 to 10M	1	200
					0.1 to 10M	2, 5	200
CMF65	CMF-65	500	1.5	1	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5	50
					10 to 10M	1, 2, 5	50
					1 to 15M	1, 2, 5	100
					0.5 to 22M	1, 2, 5	150
					0.5 to 22M	1	200
					0.1 to 22M	2, 5	200
CMF70	CMF-70	500	1.75	1.25	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5	50
					10 to 10M	1, 2, 5	50
					1 to 15M	1, 2, 5	100
					1 to 22M	1, 2, 5	150, 200
CMF07	CMF-07	250	0.5	-	5 to 5M	2, 5	100
					1 to 5M	2, 5	150, 200
CMF20	CMF-20	500	1	-	5 to 10M	2, 5	100
					1 to 10M	2, 5	150, 200

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CMF Industrial

Vishay Dale

GLOBAL PART NUMBER INFORMATION

New Global Part Numbering: CMF55301R00FKRE (preferred part numbering format)

C	M	F	5	5	3	0	1	R	0	0	F	K	R	E			

GLOBAL MODEL	RESISTANCE VALUE	TOLERANCE CODE	TEMPERATURE COEFFICIENT [(1)]	PACKAGING	SPECIAL
(See Standard Electrical Specifications table)	**R** = Ω **K** = kΩ **M** = MΩ **R10000** = 0.1 Ω **680K00** = 680 kΩ **1M0000** = 1.0 MΩ	**B** = ± 0.1 % **C** = ± 0.25 % **D** = ± 0.5 % **F** = ± 1 % **G** = ± 2 % **J** = ± 5 %	**E** = 25 ppm **H** = 50 ppm **K** = 100 ppm **L** = 150 ppm **N** = 200 ppm	**EK** = lead (Pb)-free, bulk **EA** = lead (Pb)-free, T/R (full) **EB** = lead (Pb)-free, T/R (1000 pieces) **BF** = tin/lead, bulk **RE** = tin/lead, T/R (full) **R6** = tin/lead, T/R (1000 pieces)	Blank = standard (Dash number) (Up to 3 digits) From **1 to 999** as applicable **70** = color banded, 5 bands (≤ 1 %) **80** = color banded, 4 bands (≥ 2 %) **88** = hot solder dip

Historical Part Number example: CMF-553010FT-1 (will continue to be accepted)

CMF-55	3010	F	T-1	R36
HISTORICAL MODEL	RESISTANCE VALUE	TOLERANCE CODE	TEMP. COEFFICIENT	PACKAGING

Notes

- For additional information on packaging, refer to the Through-Hole Resistor Packaging document (www.vishay.com/doc?31544).

[(1)] Tolerances of ± 0.5 % (D), ± 0.25 % (C) and ± 0.1 % (B) are available only in 50 ppm and 25 ppm temperature coefficients.

DIMENSIONS in inches (millimeters)

- *R6:*

  ⇨ Calculated value : 16.66k;
  ⇨ Standard value: 16.6k;
  ⇨ Measured Power: 59.41pW;
  ⇨ Tolerance: 1%.
  ⇨ Seller: Digikey[11];
  ⇨ Manufacturer: Vishay Dale
  ⇨ Description: RES 16.6K OHM 1/4W 1% AXIAL
  ⇨ Seller Part number: CMF5016K600FKBF-ND
  ⇨ Manufacturer Part Number: CMF5016K600FKBF

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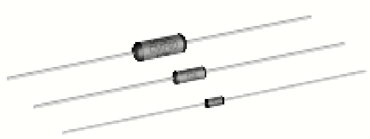
CMF Industrial
Vishay Dale

Metal Film Resistors, Axial, Industrial, Precision



FEATURES
- Small size - conformal coated
- Flame retardant epoxy coating
- Controlled temperature coefficient
- Excellent high frequency characteristics
- Exceptionally low noise; typically 0.10 μV/V
- Low voltage coefficient to ± 5 ppm/V
- Special tolerance and or TC matching available on request
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

e3
RoHS*

Note
* This datasheet provides information about parts that are RoHS-compliant and / or parts that are non-RoHS-compliant. For example, parts with lead (Pb) terminations are not RoHS-compliant. Please see the information / tables in this datasheet for details.

Vishay Dale Model CMF is also available as Military Qualified Styles RN and RL. See Vishay Dale's CMF (Military RN and RL) datasheet (www.vishay.com/doc?31027) for the MIL-SPEC ratings / attributes. (Except for marking, the Industrial and Military versions are exactly the same).

STANDARD ELECTRICAL SPECIFICATIONS

GLOBAL MODEL	HISTORICAL MODEL	MAXIMUM WORKING VOLTAGE (1) V	POWER RATING $P_{70\,°C}$ (2) W	POWER RATING $P_{125\,°C}$ (2) W	RESISTANCE RANGE Ω	TOLERANCE ± %	TEMPERATURE COEFFICIENT ± ppm/°C
CMF50	CMF-50	200	0.25	0.125	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5, 1, 2, 5	50
					10 to 2.5M	1, 2, 5	100
					10 to 22M	1, 2, 5	150, 200
CMF55	CMF-55	250	0.5	0.25	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5	50
					10 to 5M	1, 2, 5	50
					1 to 22.1M	1, 2, 5	100
					0.5 to 50M	1, 2, 5	150
					0.5 to 50M	1	200
					0.1 to 50M	2, 5	200
CMF60	CMF-60	500	1	0.5	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5	50
					10 to 10M	1, 2, 5	50
					1 to 10M	1, 2, 5	100
					0.5 to 10M	1, 2, 5	150
					0.5 to 10M	1	200
					0.1 to 10M	2, 5	200
CMF65	CMF-65	500	1.5	1	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5	50
					10 to 10M	1, 2, 5	50
					1 to 15M	1, 2, 5	100
					0.5 to 22M	1, 2, 5	150
					0.5 to 22M	1	200
					0.1 to 22M	2, 5	200
CMF70	CMF-70	500	1.75	1.25	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5	50
					10 to 10M	1, 2, 5	50
					1 to 15M	1, 2, 5	100
					1 to 22M	1, 2, 5	150, 200
CMF07	CMF-07	250	0.5	-	5 to 5M	2, 5	100
					1 to 5M	2, 5	150, 200
CMF20	CMF-20	500	1	-	5 to 10M	2, 5	100
					1 to 10M	2, 5	150, 200

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VISHAY
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CMF Industrial
Vishay Dale

GLOBAL PART NUMBER INFORMATION

New Global Part Numbering: CMF55301R00FKRE (preferred part numbering format)

C	M	F	5	5	3	0	1	R	0	0	F	K	R	E			

GLOBAL MODEL	RESISTANCE VALUE	TOLERANCE CODE	TEMPERATURE COEFFICIENT [(1)]	PACKAGING	SPECIAL
(See Standard Electrical Specifications table)	**R** = Ω **K** = kΩ **M** = MΩ **R10000** = 0.1 Ω **680K00** = 680 kΩ **1M0000** = 1.0 MΩ	**B** = ± 0.1 % **C** = ± 0.25 % **D** = ± 0.5 % **F** = ± 1 % **G** = ± 2 % **J** = ± 5 %	**E** = 25 ppm **H** = 50 ppm **K** = 100 ppm **L** = 150 ppm **N** = 200 ppm	**EK** = lead (Pb)-free, bulk **EA** = lead (Pb)-free, T/R (full) **EB** = lead (Pb)-free, T/R (1000 pieces) **BF** = tin/lead, bulk **RE** = tin/lead, T/R (full) **R6** = tin/lead, T/R (1000 pieces)	Blank = standard (Dash number) (Up to 3 digits) From **1 to 999** as applicable **70** = color banded, 5 bands (≤ 1 %) **80** = color banded, 4 bands (≥ 2 %) **88** = hot solder dip

Historical Part Number example: CMF-553010FT-1 (will continue to be accepted)

CMF-55	3010	F	T-1	R36
HISTORICAL MODEL	RESISTANCE VALUE	TOLERANCE CODE	TEMP. COEFFICIENT	PACKAGING

Notes
- For additional information on packaging, refer to the Through-Hole Resistor Packaging document (www.vishay.com/doc?31544).

(1) Tolerances of ± 0.5 % (D), ± 0.25 % (C) and ± 0.1 % (B) are available only in 50 ppm and 25 ppm temperature coefficients.

DIMENSIONS in inches (millimeters)

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- *R7:*

  - ⇨ Calculated value : 5k;
  - ⇨ Standard value: 5k;
  - ⇨ Measured Power: 6.508pW;
  - ⇨ Tolerance: 1%.
  - ⇨ Seller: Digikey[11];
  - ⇨ Manufacturer: Vishay Dale
  - ⇨ Description: RES 5K OHM 1/4W 1% AXIAL
  - ⇨ Seller Part number: 1135-1619-ND
  - ⇨ Manufacturer Part Number: RN60D5001FB14

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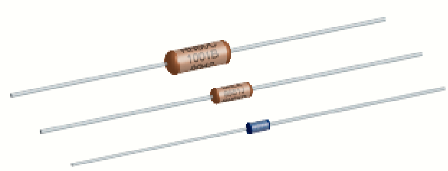
CMF (Military RN and RL)
Vishay Dale

Metal Film Resistors, Axial, Military, MIL-R-10509 Qualified, Precision, Type RN and MIL-PRF-22684 Qualified, Type RL



FEATURES

- Very low noise (-40 dB)
- Very low voltage coefficient (5 ppm/V)
- Controlled temperature coefficient
- Flame retardant epoxy coating
- Commercial alternatives to military styles are available with higher power ratings. See CMF Industrial data sheet: (www.vishay.com/doc?31018)

STANDARD ELECTRICAL SPECIFICATIONS

GLOBAL MODEL	MIL STYLE	MIL SPEC. SHEET	POWER RATING $P_{70\,°C}$ W	POWER RATING $P_{125\,°C}$ W	MAX. WORKING VOLTAGE (1) V	RESISTANCE RANGE Ω MIL-R-10509 ± 100 ppm/°C (D)	RESISTANCE RANGE Ω MIL-R-10509 ± 50 ppm/°C (C)	RESISTANCE RANGE Ω MIL-R-10509 ± 25 ppm/°C (E)	RESISTANCE RANGE Ω MIL-PRF-22684	TOL. (3) ± %	DIELECTRIC STRENGTH V_{AC}
CMF50	RN50	08	-	0.05	200	-	10 to 100K	10 to 100K	-	0.1, 0.25, 0.5, 1	450
CMF55	RN55	07	0.125	0.10	200	10 to 301K	49.9 to 100K	49.9 to 100K	-	0.1, 0.25, 0.5, 1	450
CMF60	RN60	01	0.25	0.125	300	10 to 1M	49.9 to 499K	49.9 to 499K	-	0.1, 0.25, 0.5, 1	500
CMF65	RN65	02	0.50	0.25	350	10 to 2M	49.9 to 1M	49.9 to 1M	-	0.1, 0.25, 0.5, 1	900
CMF70	RN70	03	0.75 (2)	0.50	500	10 to 2.49M	24.9 to 1M	24.9 to 1M	-	0.1, 0.25, 0.5, 1	900
CMF07	RL07	01	0.25	-	250	-	-	-	51 to 150K	2, 5	450
CMF20	RL20	02	0.50	-	350	-	-	-	4.3 to 470K	2, 5	700

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CMF (Military RN and RL)
Vishay Dale

GLOBAL PART NUMBER INFORMATION

New Global Part Numbering: RN60D3483FR36 (preferred part numbering format)

R	N	6	0	D	3	4	8	3	F	R	3	6			

MIL STYLE	CHARACTERISTIC	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING	SPECIAL
RN50 **RN55** **RN60** **RN65** **RN70**	**E** = 25 ppm **C** = 50 ppm **D** = 100 ppm	3 digit significant figure, followed by a multiplier Use "R" for values < 100 Ω **10R0** = 10 Ω **2152** = 21.5 kΩ **2494** = 2.49 MΩ	**B** = ± 0.1 % **C** = ± 0.25 % **D** = ± 0.5 % **F** = ± 1 %	**B14** = tin/lead, bulk **BSL** = tin/lead, bulk, single lot date code **R36** = tin/lead, T/R (full) **RE6** = tin/lead, T/R (1000 pieces) **RSL** = tin/lead, T/R, single lot date code	Blank = standard (Dash number) **88** = hot solder dip **143** = non-magnetic

Historical Part Number example: RN60D3483F (will continue to be accepted)

RN60	D	3483	F	R36
MIL STYLE	CHARACTERISTIC	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING

New Global Part Numbering: RL07S471JR36 (preferred part numbering format)

R	L	0	7	S	4	7	1	J	R	3	6			

MIL STYLE	LEAD MATERIAL	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING	SPECIAL
RL07 **RL20**	**S** = solderable	2 digit significant figure, followed by a multiplier Use "R" for values < 10 Ω **4R3** = 4.3 Ω **202** = 2.0 kΩ **474** = 470 kΩ	**G** = ± 2 % **J** = ± 5 %	**B14** = tin/lead, bulk **BSL** = tin/lead, bulk, single lot date code **R36** = tin/lead, T/R (full) **RE6** = tin/lead, T/R (1000 pieces) **RSL** = tin/lead, T/R, single lot date code	Blank = standard (Dash number) **88** = hot solder dip **143** = non-magnetic

Historical Part Number example: RL07S471J (will continue to be accepted)

RL07	S	471	J	R36
MIL STYLE	LEAD MATERIAL	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING

- *R8:*

  - ⇨ Calculated value : 10k;
  - ⇨ Standard value: 10k;
  - ⇨ Measured Power: 5.619pW;
  - ⇨ Tolerance: 1%.
  - ⇨ Seller: Digikey[11];
  - ⇨ Manufacturer: Yageo
  - ⇨ Description: RES 10K OHM 1/4W 1% AXIAL
  - ⇨ Seller Part number: 10.0KXTR-ND
  - ⇨ Manufacturer Part Number: MFR-25FRF52-10K

ELECTRICAL CHARACTERISTICS

STYLE	MFR-12	MFR25S	MFR-25	MFR50S	MFR-50	MFR1WS	MFR100	MFR2WS	MFR200	MFR3WS
Power Rating at 70°C	1/6W	1/4W		1/2W		1W		2W		3W
Maximum Working Voltage	200V		250V	300V	350V	400V	500V			
Maximum Overload Voltage	400V		500V	600V	700V	800V	1,000V			
Voltage Proof on Insulation	300V	400V	500V			700V	1,000V			
Resistance Range	1Ω - 4M7Ω & for E24 & E96 series value									
Operating Temp. Range	-55°C to +155°C									
Temperature Coefficient	±50ppm/°C, ±100ppm/°C									

Note: Special value is available on request

- *R9*:
  - ⇨ Calculated value : 3.333k;
  - ⇨ Standard value: 3.3k;
  - ⇨ Measured Power: 11.81pW;
  - ⇨ Tolerance: 1%.
  - ⇨ Seller: Digikey[11];
  - ⇨ Manufacturer: Stackpole Electronics Inc
  - ⇨ Description: RES 3.3K OHM 1/4W 1% AXIAL
  - ⇨ Seller Part number: S3.3KCACT-ND
  - ⇨ Manufacturer Part Number: RNMF14FTC3K30

RNF / RNMF Series

General Purpose Metal Film Resistor

Stackpole Electronics, Inc.

Resistive Product Solutions

Features:

- Precision metal film
- Superior electrical, TCR performances
- Flame-retardant coatings are standard
- Panasert available (selected sizes: contact factory)
- RNMF (mini) an ideal choice where size constraints apply
- RNF 5% replaces MP series
- Lower or higher resistance values may be possible (contact factory)
- RoHS compliant, lead free and halogen free

Electrical Specifications

Type / Code	Mil Ref	Power Rating (W)	Maximum Working Voltage	Maximum Overload Voltage	TCR	Ohmic Range (Ω) and Tolerance						
						0.05%	0.1%	0.25%	0.5%	1%	2%	5%
RNF18	RN 50	0.125	200	400	± 10 ppm/°C ± 25 ppm/°C ± 50 ppm/°C ± 100 ppm/°C	100 - 100 K	100 - 100 K 51.1 - 100 K	100 - 100 K	100 - 100 K 30.1 - 499 K 10 - 1 M	100 - 100 K 49.9 - 499 K 1 - 1M 1 - 10 M	- 1 - 22 M	
RNMF14	-	0.25	200	400	± 25 ppm/°C ± 50 ppm/°C ± 100 ppm/°C	-	100 - 100 K		30.1 - 499 K 10 - 1 M	30.1 - 499 K 1 - 1 M 1 - 2.15 M	- 1 - 2.2 M	
RNF14	RN 55	0.25	250	500	± 10 ppm/°C ± 25 ppm/°C ± 50 ppm/°C ± 100 ppm/°C	100 - 100 K	100 - 100 K 1 - 2.2 M	-		10 - 1 M 1 - 5.11 M 1 - 10 M	- 5.6 - 10 M	- 1.1 M - 10 M 1 - 10 M
RNMF12	RL 07	0.5	350	600	± 25 ppm/°C ± 50 ppm/°C ± 100 ppm/°C	-	30.1 - 294 K 30.1 - 1 M		49.9 - 1 M 10 - 1 M	1 - 1M 1 - 10 M	- 1 - 10 M	
RNF12	RN 60	0.5	350	700	± 25 ppm/°C ± 50 ppm/°C ± 100 ppm/°C	100 - 100 K			49.9 - 499 K 10 - 1 M	1 - 4.99 M 1 - 10 M	- 1 - 10 M	
RNF1	RN 65	1	350	700	± 25 ppm/°C ± 50 ppm/°C ± 100 ppm/°C	-			- 10 - 1 M	10 - 470 K 1 - 1 M	-	- 10 - 470 K 1 - 1 M
RNF2	-	2	350	800	± 25 ppm/°C ± 50 ppm/°C ± 100 ppm/°C	-				- 10 - 1 M	-	- 10 - 1 M

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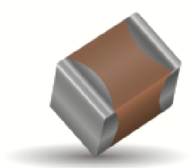
- *C1*:

  - ⇨ Calculated value : 50nF;
  - ⇨ Standard value: 0.05uF (which is equal to 50nF);
  - ⇨ Tolerance: 5%
  - ⇨ Seller: Digikey[11];
  - ⇨ Manufacturer: AVX Corporation
  - ⇨ Description: CAP CER 0.05UF 50V X7R 1206
  - ⇨ Seller Part number: 12065C503JAT2A-ND
  - ⇨ Manufacturer Part Number: 12065C503JAT2A

X7R Dielectric

General Specifications



X7R formulations are called "temperature stable" ceramics and fall into EIA Class II materials. X7R is the most popular of these intermediate dielectric constant materials. Its temperature variation of capacitance is within ±15% from -55°C to +125°C. This capacitance change is non-linear.

Capacitance for X7R varies under the influence of electrical operating con-ditions such as voltage and frequency.

X7R dielectric chip usage covers the broad spectrum of industrial applications where known changes in capacitance due to applied voltages are acceptable.

RoHS COMPLIANT

PART NUMBER (SEE PAGE 4 FOR COMPLETE PART NUMBER EXPLANATION)

0805	5	C	103	M	A	T	2	A
Size (L" x W")	**Voltage** 4V = 4 6.3V = 6 10V = Z 16V = Y 25V = 3 50V = 5 100V = 1 200V = 2 500V = 7	**Dielectric** X7R = C	**Capacitance** Code (In pF) 2 Sig. Digits + Number of Zeros	**Capacitance Tolerance** J = ± 5%* K = ±10% M = ± 20% *≤1μF only, contact factory for additional values	**Failure Rate** A = Not Applicable	**Terminations** T = Plated Ni and Sn Z= FLEXITERM®** *Optional termination **See FLEXITERM® X7R section	**Packaging** 2 = 7" Reel 4 = 13" Reel **Contact Factory For Multiples**	**Special Code** A = Std. Product

NOTE: Contact factory for availability of Termination and Tolerance Options for Specific Part Numbers.

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X7R Dielectric

Specifications and Test Methods

Parameter/Test		X7R Specification Limits	Measuring Conditions	
Operating Temperature Range		-55°C to +125°C	Temperature Cycle Chamber	
Capacitance		Within specified tolerance	Freq.: 1.0 kHz ± 10% Voltage: 1.0Vrms ± .2V For Cap > 10µF, 0.5Vrm @ 120Hz	
Dissipation Factor		≤ 10% for ≥ 50V DC ratings 12.5% for 25V DC rating ≤ 12.5% for 25V and 16V DC rating ≤ 12.5% for ≤ 10V DC rating Contact Factory for DF by PN		
Insulation Resistance		100,000MΩ or 1000MΩ - µF, whichever is less	Charge device with rated voltage for 120 ± 5 secs @ room temp/humidity	
Dielectric Strength		No breakdown or visual defects	Charge device with 250% of rated voltage for 1-5 seconds, w/charge and discharge current limited to 50 mA (max) Note: Charge device with 150% of rated voltage for 500V devices.	
Resistance to Flexure Stresses	Appearance	No defects	Deflection: 2mm Test Time: 30 seconds	
	Capacitance Variation	≤ ±12%		
	Dissipation Factor	Meets Initial Values (As Above)		
	Insulation Resistance	≥ Initial Value x 0.3		
Solderability		≥ 95% of each terminal should be covered with fresh solder	Dip device in eutectic solder at 230 ± 5°C for 5.0 ± 0.5 seconds	
Resistance to Solder Heat	Appearance	No defects, <25% leaching of either end terminal	Dip device in eutectic solder at 260°C for 60 seconds. Store at room temperature for 24 ± 2hours before measuring electrical properties.	
	Capacitance Variation	≤ ±7.5%		
	Dissipation Factor	Meets Initial Values (As Above)		
	Insulation Resistance	Meets Initial Values (As Above)		
	Dielectric Strength	Meets Initial Values (As Above)		
Thermal Shock	Appearance	No visual defects	Step 1: -55°C ± 2°	30 ± 3 minutes
	Capacitance Variation	≤ ±7.5%	Step 2: Room Temp	≤ 3 minutes
	Dissipation Factor	Meets Initial Values (As Above)	Step 3: +125°C ± 2°	30 ± 3 minutes
	Insulation Resistance	Meets Initial Values (As Above)	Step 4: Room Temp	≤ 3 minutes
	Dielectric Strength	Meets Initial Values (As Above)	Repeat for 5 cycles and measure after 24 ± 2 hours at room temperature	
Load Life	Appearance	No visual defects	Charge device with 1.5 rated voltage (≤ 10V) in test chamber set at 125°C ± 2°C for 1000 hours (+48, -0) If RV > 10V then Life Test voltage will be 2xRV but there are exceptions (please contact AVX for further details on exceptions) Remove from test chamber and stabilize at room temperature for 24 ± 2 hours before measuring.	
	Capacitance Variation	≤ ±12.5%		
	Dissipation Factor	≤ Initial Value x 2.0 (See Above)		
	Insulation Resistance	≥ Initial Value x 0.3 (See Above)		
	Dielectric Strength	Meets Initial Values (As Above)		
Load Humidity	Appearance	No visual defects	Store in a test chamber set at 85°C ± 2°C/ 85% ± 5% relative humidity for 1000 hours (+48, -0) with rated voltage applied. Remove from chamber and stabilize at room temperature and humidity for 24 ± 2 hours before measuring.	
	Capacitance Variation	≤ ±12.5%		
	Dissipation Factor	≤ Initial Value x 2.0 (See Above)		
	Insulation Resistance	≥ Initial Value x 0.3 (See Above)		
	Dielectric	Meets Initial Values (As Above)		

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- *Rpot1 and Rpot2*:
  - ⇨ Calculated value : 10k;
  - ⇨ Standard value: 10k;
  - ⇨ Tolerance: 5%
  - ⇨ Seller: Digikey[11];
  - ⇨ Manufacturer: Bourns Inc.
  - ⇨ Description: POT 10K OHM 2W WIREWOUND LINEAR
  - ⇨ Seller Part number: 3540S-1-103L-ND
  - ⇨ Manufacturer Part Number: 3540S-1-103L

Features

- Bushing mount
- Optional center tap and rear shaft extension
- Optional AR lug feature
- Gangable with common or concentric shafts
- High torque available
- Non-standard features and specifications available
- RoHS compliant*

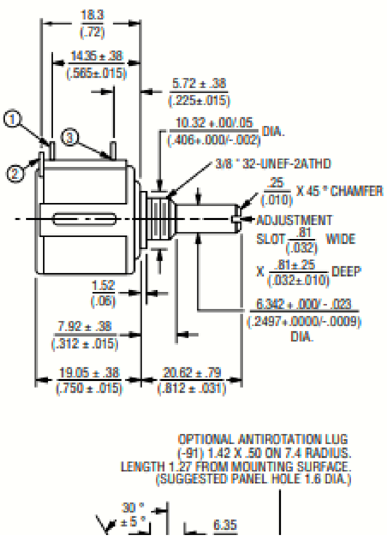
3540/3541 - Precision Potentiometer

Electrical Characteristics[1]	3540 Wirewound Element	3541 Hybritron® Element
Standard Resistance Range	100 to 100 K ohms	1 K to 100 K ohms
Total Resistance Tolerance	±5 %	±10 %
Independent Linearity	±0.25 %	±0.25 %
Effective Electrical Angle	3600 ° +10 °, -0 °	3600 ° +10 °, -0 °
Absolute Minimum Resistance/ Minimum Voltage	1 ohm or 0.1 % maximum (whichever is greater)	0.2 % maximum
Noise/Output Smoothness	100 ohms ENR maximum	0.1 % maximum
Dielectric Withstanding Voltage (MIL-STD-202, Method 301)		
Sea Level	1,000 VAC minimum	1,000 VAC minimum
Power Rating (Voltage Limited By Power Dissipation or 447 VAC, Whichever Is Less)		
+70 °C	2 watts	2 watts
+125 °C	0 watt	0 watt
Insulation Resistance (500 VDC)	1,000 megohms minimum	1,000 megohms minimum
Resolution	See recommended part nos.	Essentially infinite

Environmental Characteristics[1]		
Operating Temperature Range	-40 °C to +125 °C	-40 °C to +125 °C
Storage Temperature Range	-55 °C to +125 °C	-55 °C to +125 °C
Temperature Coefficient Over Storage Temperature Range[2]	±50 ppm/°C maximum/unit	±100 ppm/°C maximum/unit
Vibration	15 G	15 G
Wiper Bounce	0.1 millisecond maximum	0.1 millisecond maximum
Shock	50 G	50 G
Wiper Bounce	0.1 millisecond maximum	0.1 millisecond maximum
Load Life	1,000 hours, 2 watts	1,000 hours, 2 watts
Total Resistance Shift	±2 %	±5 %
Rotational Life (No Load)	1,000,000 shaft revolutions[2]	5,000,000 shaft revolutions[2]
Total Resistance Shift	±5 % maximum	±5 % maximum
Moisture Resistance (MIL-STD-202, Method 103, Condition B)		
Total Resistance Shift	±2 % maximum	±5 % maximum
IP Rating	IP 40	IP 40

Product Dimensions

3540S-1/3541H-1



- *TA75557P:*
  - ⇨ Seller: UTsource[14];
  - ⇨ Manufacturer: Toshiba
  - ⇨ Slew Rate: 1V/us;
  - ⇨ Input Bias Current: max 500nA
  - ⇨ Max Supply voltage: ±18V

TOSHIBA TA75557P/S/F

MAXIMUM RATINGS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	TA75557P TA75557S	TA75557F	UNIT
Supply Voltage	V_{CC}, V_{EE}	+ 18	+ 18	V
		− 18	− 18	
Differential Input Voltage	DV_{IN}	± 30	± 30	V
Input Voltage	V_{IN}	V_{CC}~V_{EE}	V_{CC}~V_{EE}	V
Power Dissipation	P_D	500	240	mW
Operating Temperature	T_{opr}	− 40~85	− 30~70	°C
Storage Temperature	T_{stg}	− 55~125	− 55~125	°C

MAXIMUM RATINGS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	TA75557P TA75557S	TA75557F	UNIT
Supply Voltage	V_{CC}, V_{EE}	+ 18	+ 18	V
		− 18	− 18	
Differential Input Voltage	DV_{IN}	± 30	± 30	V
Input Voltage	V_{IN}	V_{CC}~V_{EE}	V_{CC}~V_{EE}	V
Power Dissipation	P_D	500	240	mW
Operating Temperature	T_{opr}	− 40~85	− 30~70	°C
Storage Temperature	T_{stg}	− 55~125	− 55~125	°C

ELECTRICAL CHARACTERISTICS (V_{CC} = 15V, V_{EE} = − 15V, Ta = 25°C)

CHARACTERISTIC	SYMBOL	TEST CIR-CUIT	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Input Offset Voltage	V_{IO}	1	$R_g \leq 10k\Omega$	—	0.5	6	mV
Input Offset Current	I_{IO}	2	—	—	5	200	nA
Input Bias Current	I_I	2	—	—	60	500	nA
Common Mode Input Voltage	CMV_{IN}	3	—	± 12	± 14	—	V
Maximum Output Voltage	V_{OM}	6	$R_L = 10k\Omega$	± 12	± 14	—	V
	V_{OMR}		$R_L = 2k\Omega$	± 10	± 13	—	
Source Current	I_{source}	8	—	27	—	—	mA
Sink Current	I_{sink}	7	—	27	—	—	mA
Voltage Gain (Open Loop)	G_V	5	$V_{OUT} = \pm 10V$, $R_L = 2k\Omega$	86	100	—	dB
Common Mode Input Signal Rejection Ratio	CMRR	3	$R_g \leq 10k\Omega$	70	90	—	dB
Supply Voltage Rejection Ratio	SVRR	1	$R_g \leq 10k\Omega$	—	30	150	μV / V
Slew Rate	SR	9	$G_V = 1$, $R_L = 2k\Omega$	—	1.0	—	V / μs
Unity Gain Cross Frequency	f_T	5	Open Loop	—	3.0	—	MHz
Supply Current	I_{CC}, I_{EE}	4	—	—	4.0	6.0	mA
Equivalent Input Noise Voltage	V_{NI}	—	$R_S = 1k\Omega$, f = 30Hz~30kHz	—	2.5	—	μV_{rms}

- TL082:
  - ⇨ Seller: DigiKey[11];
  - ⇨ Manufacturer: Texas Instruments
  - ⇨ Slew Rate: 13V/us;
  - ⇨ Input Bias Current: max 400pA
  - ⇨ Supply voltage: Max ±18V

TL082

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	±18V
Power Dissipation	(Note 2)
Operating Temperature Range	0˚C to +70˚C
$T_{j(MAX)}$	150˚C
Differential Input Voltage	±30V
Input Voltage Range (Note 3)	±15V
Output Short Circuit Duration	Continuous
Storage Temperature Range	−65˚C to +150˚C
Lead Temp. (Soldering, 10 seconds)	260˚C

ESD rating to be determined.

Note 1: "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits.

DC Electrical Characteristics (Note 5)

Symbol	Parameter	Conditions	TL082C			Units
			Min	Typ	Max	
V_{OS}	Input Offset Voltage	R_S = 10 kΩ, T_A = 25˚C		5	15	mV
		Over Temperature			20	mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	R_S = 10 kΩ		10		µV/˚C
I_{OS}	Input Offset Current	T_j = 25˚C, (Notes 5, 6)		25	200	pA
		$T_j \le$ 70˚C			4	nA
I_B	Input Bias Current	T_j = 25˚C, (Notes 5, 6)		50	400	pA
		$T_j \le$ 70˚C			8	nA
R_{IN}	Input Resistance	T_j = 25˚C		10^{12}		Ω
A_{VOL}	Large Signal Voltage Gain	V_S = ±15V, T_A = 25˚C V_O = ±10V, R_L = 2 kΩ	25	100		V/mV
		Over Temperature	15			V/mV
V_O	Output Voltage Swing	V_S = ±15V, R_L = 10 kΩ	±12	±13.5		V
V_{CM}	Input Common-Mode Voltage Range	V_S = ±15V	±11	+15		V
				−12		V
CMRR	Common-Mode Rejection Ratio	$R_S \le$ 10 kΩ	70	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 7)	70	100		dB
I_S	Supply Current			3.6	5.6	mA

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