Faculty of Electronics, Telecommunications and Information Technology

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TECHNICAL UNIVERSITY OF CLUJ-NAPOCA ROMANIA

COMPUTER AIDED DESIGN

- AUDIO AMPLIFIER -

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Group: 2023

1. INTRODUCTION

1.1 About CAD

Computer-aided design (CAD) is the use of computers (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. Designs made through CAD software are helpful in protecting products and inventions when used in patent applications. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for computer aided design and drafting) is also used.

Its use in designing electronic systems is known as electronic design automation (EDA). In mechanical design it is known as mechanical design automation (MDA) or computer-aided drafting (CAD), which includes the process of creating a technical drawing with the use of computer software.

1.2. About OrCAD

OrCAD Systems Corporation was a software company that made OrCAD, a proprietary software tool suite used primarily for electronic design automation (EDA). The software is used mainly by electronic design engineers and electronic technicians to create electronic schematics, perform mixed-signal simulation and electronic prints for manufacturing printed circuit boards. OrCAD was taken over by Cadence Design Systems in 1999 and was integrated with Cadence Allegro since 2005. The name OrCAD is a portmanteau, reflecting the company and its software's origins: Oregon + CAD.

OrCAD Capture is a schematic capture application, and part of the OrCAD circuit design suite.Unlike NI Multisim, Capture does not contain in-built simulation features, but exports netlist data to the simulator, OrCAD EE. Capture can also export a hardware description of the circuit schematic to Verilog or VHDL, and netlists to circuit board designers such as OrCAD Layout, Allegro, and others.

Capture includes a component information system (CIS), that links component package footprint data or simulation behavior data, with the circuit symbol in the schematic.

Capture can interface with any database which complies with Microsoft's ODBC standard etc. Data in an MRP, ERP, or PDM system can be directly accessed for use during component decision-making process.

1.3. Project Requirements

Design an audio amplifier knowing the next parameters:

The amplitude of the input voltage = 800μΩ

Bandwidth between [512 - 2,048] Hz

The amplitude of the output voltage between [5, 7] V

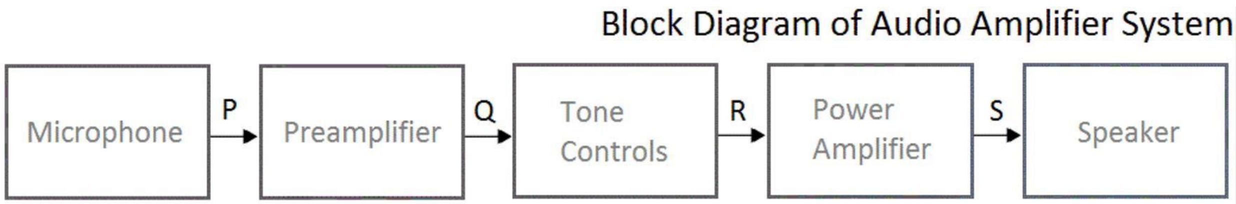
Output resistance = 40Ω.

1.4. Generalities about the Audio Amplifier

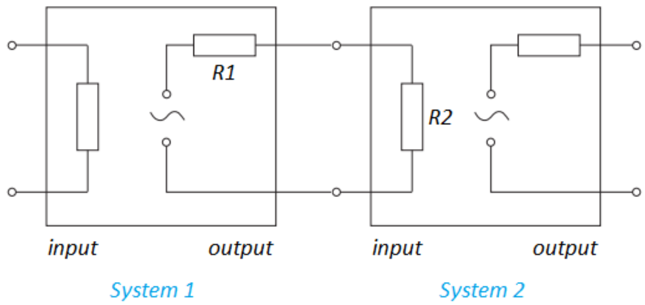
Audio is one of the most common media. Here, It refers to the representation of sound which can be perceived by humans. Audio and Video are the essential component of any electronic media. The electronics can be used to receive audio signals (via microphone), record audio in some storage, transmit audio (through wired or wireless communication channels) and reproduce audio signals (via speakers). The audio can be represented and transmitted as either analog signals or digital signals. In this series, analog audio signals are the concern. The audio signals have a frequency range of 20 Hz to 20,000 Hz.

The loudness of an audio signal is signified by the amplitude of the signal. Like the nature of sound, the audio in the form of electrical signals also fade away with the distance. This was a major problem before the telephony engineers in the initial phase of the development of communication technologies. Typically, on a wired channel, if an electrical signal carrying audio is transmitted from one end and received at another end one mile away, it loses 90 percent of its strength. When the signal travels through a wire, the resistance of the wire causes reduction in its power (P = I2/R). The loss of signal over transmission has been a major issue before the electronic engineers. There are losses whether the signal is transmitted from just the microphone to the recording device, computer or audio generator to a speaker or it is transmitted on wire over a long distance. In order to sort out this problem, engineers devised special electronics – ‘Amplifiers’. The amplifiers increases the strength of the signal so it reaches a longer distance before diminishing. By increasing the amplitude of the input signal, basically the output power of the circuit is increased as high power signals can travel more distance than low power signals. By using amplifiers at different stages, the audio signals can then be safely transmitted over a wired connection.

1.4.1. Working principle

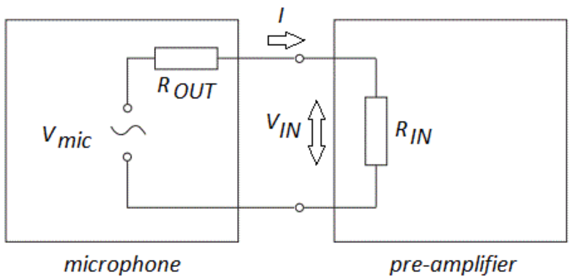


This block diagram of an audio system shows all the stages from microphone to speaker and follows the design of a typical PA system. The links between the subsystems are P, Q, R, S, and it is important to understand their nature, because they are responsible for minimising signal losses in a well-designed system.

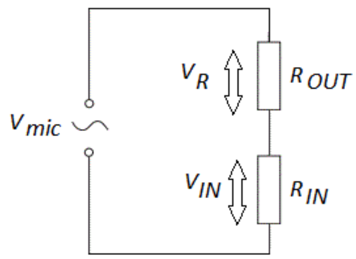


Generally, in order to maximise voltage transfer between systems, the input impedance of system 2 has to be greater that the output impedance of system 1. Therefore, R2 has to be greater than R1 as shown above.

Microphone and Preamplifier Blocks



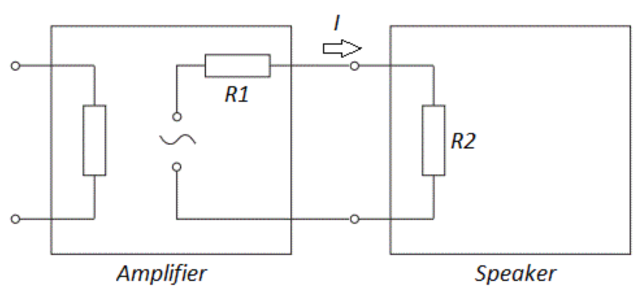
Microphones produce very small ac signals that have to travel across long wires to the preamplifier; therefore, impedance is vital at this first stage to prevent signal loss. Usually, preamplifiers, consist of non-inverting op-amps that provide voltage amplification. This is because they have very high input impedance and therefore draw less current from the source making them ideal for this application.



As you can see, the input impedances form a *potential divider* network. In order to increase V_{IN}, we must increase R_{IN}. We achieve this using an operational amplifier, which has high input impedance. Typically, a voltage follower works well in this situation.

The tone control block usually consists of an active filter that provides boost and cut facility of treble and bass.

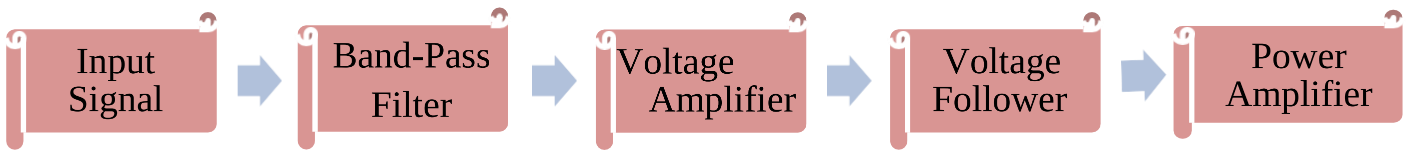
Power Amplifier and Speaker Blocks



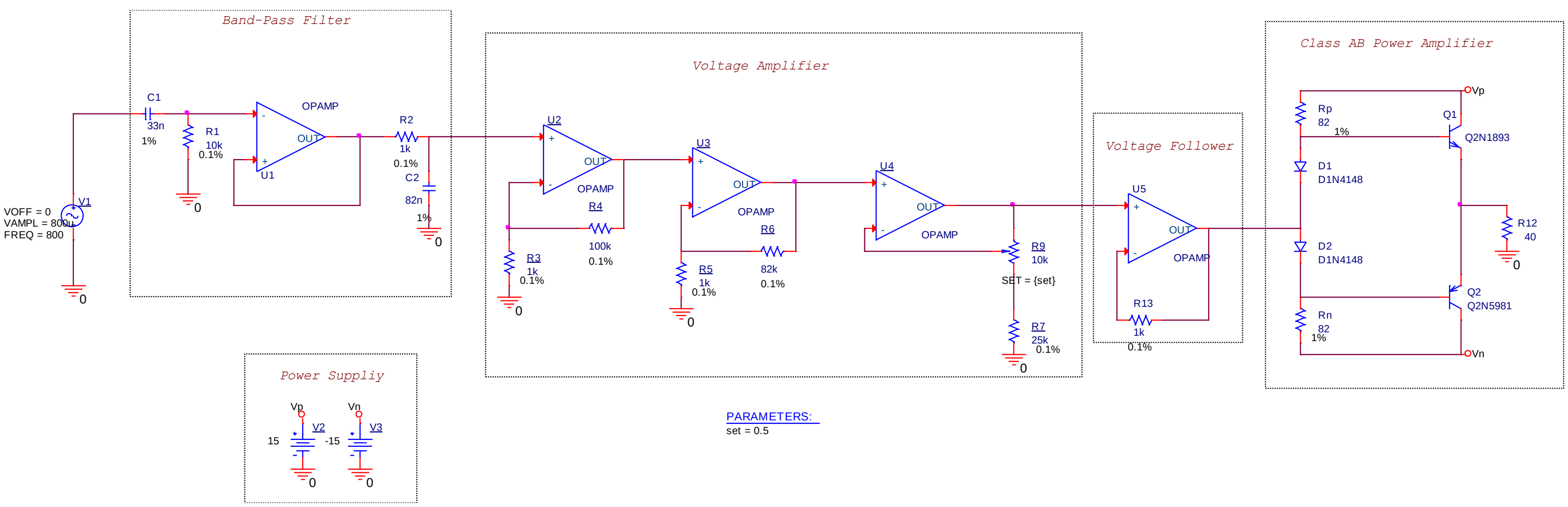
The *power amplifier* is concerned with driving the load, which is usually a loudspeaker. Here, we are concerned with maximising the transfer of *power* to the load, and not the voltage. This is because if we were to increase the resistance of the speaker, the current would reduce, thereby reducing the power output. Therefore, here at the last stage, we want to maximise current, and therefore it is desirable to keep the resistance to minimum (but within specification of course). Therefore, to maximise the power transfer between these two stages, R1 = R2.

2. ELECTRICAL SCHEMATIC AND BLOCK DIAGRAM

2.1. Block Diagram



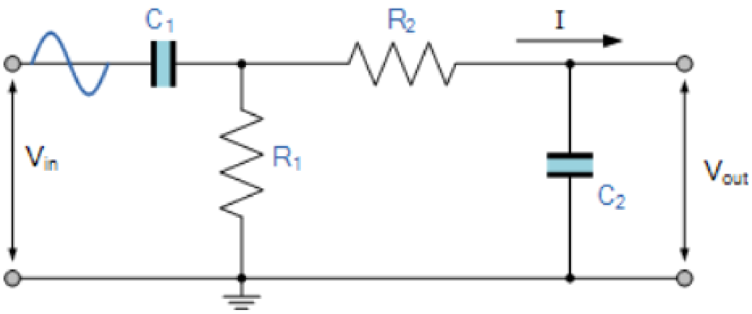
2.2. The electrical schematic



[1]

[1] The real project would be implemented with UA741 OpAmp with VCC +-15, but OrCad Capture – Lite doesn't allow the simulation due to too many nodes so I used the analog ones instead, that are ideal.

2.2.1 Band-Pass Filter



$$fc = \frac{1}{2\pi RC}\ Hz$$

$$C_1 = \frac{1}{2\pi f_L R} \qquad C_2 = \frac{1}{2\pi f_H R}$$

Band Pass Filters can be used to isolate or filter out certain frequencies that lie within a particular band or range of frequencies. The cut-off frequency or $ƒc$ point in a simple RC passive filter can be accurately controlled using just a single resistor in series with a non-polarized capacitor, and depending upon which way around they are connected, we have seen that either a Low Pass or a High Pass filter is obtained.

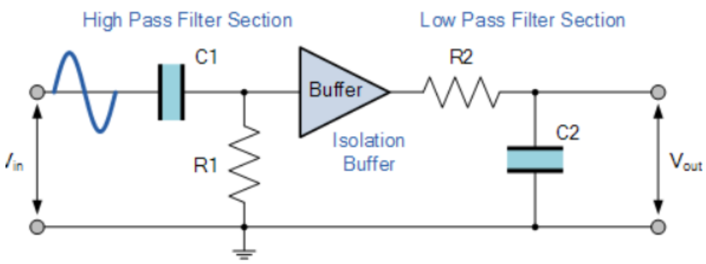
One simple use for these types of passive filters is in audio amplifier applications or circuits such as in loudspeaker crossover filters or pre-amplifier tone controls. Sometimes it is necessary to only pass a certain range of frequencies that do not begin at 0Hz, (DC) or end at some upper high frequency point but are within a certain range or band of frequencies, either narrow or wide.

By connecting or "cascading" together a single **Low Pass Filter** circuit with a **High Pass Filter** circuit, we can produce another type of passive RC filter that passes a selected range or "band" of frequencies that can be either narrow or wide while attenuating all those outside of this range. This new type of passive filter arrangement produces a frequency selective filter known commonly as a **Band Pass Filter** or **BPF** for short.

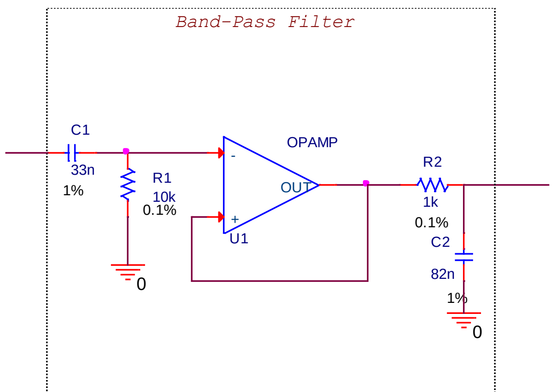
Unlike the low pass filter which only pass signals of a low frequency range or the high pass filter which pass signals of a higher frequency range, a **Band Pass Filters** passes signals within a certain "band" or "spread" of frequencies without distorting the input signal or introducing extra noise. This band of frequencies can be any width and is commonly known as the filters **Bandwidth**.

Bandwidth is commonly defined as the frequency range that exists between two specified frequency cut-off points ($ƒc$), that are 3dB below the maximum centre or resonant peak while attenuating or weakening the others outside of these two points.

One way of combining amplification and filtering into the same circuit would be to use an Operational Amplifier or Op-amp



In our case we need to have a **bandwidth between 512 Hz and 2048 Hz**. To obtain the best result we will use an *inverting band pass filter circuit* in order to filter and also amplify our circuit. We’re using an uA741 OpAmp.

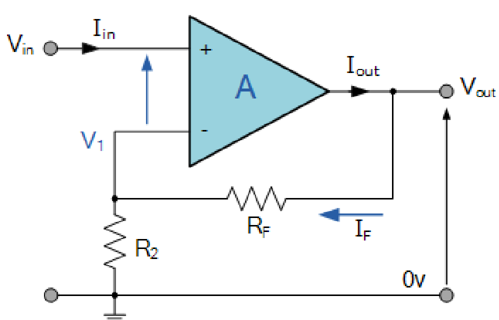


Calculations:

Assuming R1=10k, C1= $\frac{1}{2*3.14*512*10000} = 31.1n = 33\text{n}$

Assuming R2=1k, C2= $\frac{1}{2*3.14*2048*1000} = 77.7n = 82n$

2.2.2 Voltage Amplifier



$$V_1 = \frac{R_2}{R_2 + R_F} \times V_{OUT}$$

Ideal Summing Point: $V_1 = V_{IN}$

Voltage Gain, $A_{(V)}$ is equal to: $\frac{V_{OUT}}{V_{IN}}$

Then, $A_{(V)} = \frac{V_{OUT}}{V_{IN}} = \frac{R_2 + R_F}{R_2}$

Transpose to give: $A_{(V)} = \frac{V_{OUT}}{V_{IN}} = 1 + \frac{R_F}{R_2}$

Negative Feedback[2]

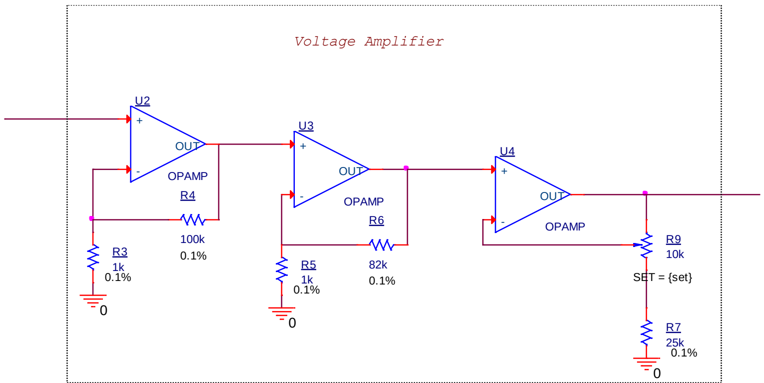
$$v^+ = v^-$$

$$v^+ = v_{in}$$

$$v^- = \frac{R_2}{R_2 + R_F} * v_0$$

[2] In negative feedback, the feedback energy (voltage or current), is out of phase with the input signal and thus opposes it. Negative feedback reduces gain of the amplifier. It also reduce distortion, noise and instability. This feedback increases bandwidth and improves input and output impedances.[2]

We can see from the equation above, that the overall closed-loop gain of a non-inverting amplifier will always be greater but never less than one (unity), it is positive in nature and is determined by the ratio of the values of Rf and R2. If the value of the feedback resistor Rf is zero, the gain of the amplifier will be exactly equal to one (unity). If resistor R2 is zero the gain will approach infinity, but in practice it will be limited to the operational amplifiers open-loop differential gain, (A_O).



In our case, we need the amplitude of the ouput voltage to be **between 5V and 7V**. In order to do this we will use 2 non inverting OpAmps for the amplification and one with a potentiometer to create the needed range.

$$A_v = \frac{V_0}{V_{in}}$$

$Av = \frac{5V}{800\mu V} = 6250$ - too big, so we take A1=100 and A2=62.5

- A1=100

$$A_1 = 1 + \frac{R_4}{R_3}$$

$$\frac{R_4}{R_3} = 99$$

$$R3 = 1k \ and \ R4 = 99k = 100k$$

- A2=62.5

$$A_1 = 1 + \frac{R_6}{R_5}$$

$$\frac{R_6}{R_5} = 61.5$$

$R5 = 1k \ and \ R6 = 61.5k = 82k$[3]

[3] We need more amplification because the filter attenuation doesn't reach 0 db.

- V_{out} = [5,7]V

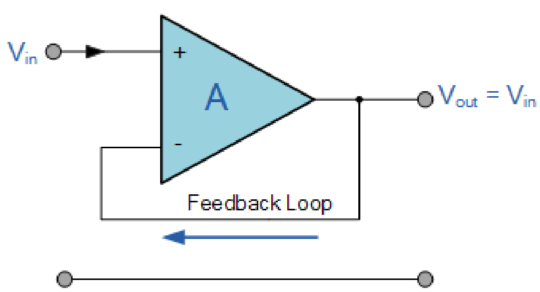
$$v^+ = 5V$$

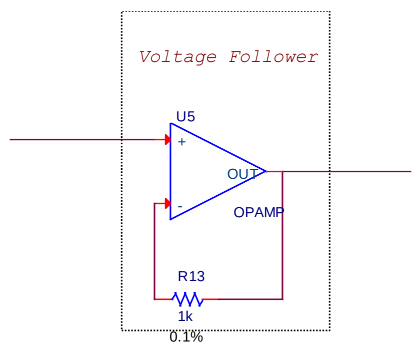
$$v^- = \frac{R_7 + kR_9}{R_7 + R_9} * v_0$$

$$\frac{R_7 + kR_9}{R_7 + R_9} * vout = 5V$$

  - k=0 $\frac{R_7}{R_7+R_9} = \frac{5}{voutmax} = \frac{5}{7}$, assuming R9=10k, R7=25k
  - k=1 $\frac{R_7+R_9}{R_7+R_9} = \frac{5}{voutmin} = \frac{5}{5}$, which is true

2.2.3 Voltage Follower





In this non-inverting circuit configuration, the input impedance Rin has increased to infinity and the feedback impedance Rf reduced to zero. The output is connected directly back to the negative inverting input so the feedback is 100% and Vin is exactly equal to Vout giving it a fixed gain of 1 or unity. As the input voltage Vin is applied to the non-inverting input, the voltage gain of the amplifier is therefore given as:

$$V_{out} = A(V_{in})$$

$$(V_{in} = V+) \text{ and } (V_{out} = V-)$$

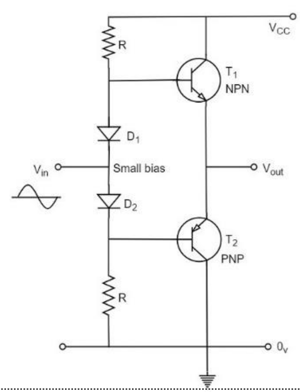
$$\text{therefore Gain, } (A_V) = \frac{V_{out}}{V_{in}} = +1$$

The *voltage follower* or unity gain buffer is a special and very useful type of Non-inverting amplifier circuit that is commonly used in electronics to isolated circuits from each other especially in High-order state variable or Sallen-Key type active filters to separate one filter stage from the other.

Since no current flows into the non-inverting input terminal the input impedance is infinite (ideal conditions) so zero current will flow through the feedback loop. Thus any value of resistance may be placed in the feedback loop without affecting the characteristics of the circuit as no current flows through it so there is zero voltage drop across it resulting in zero power loss.

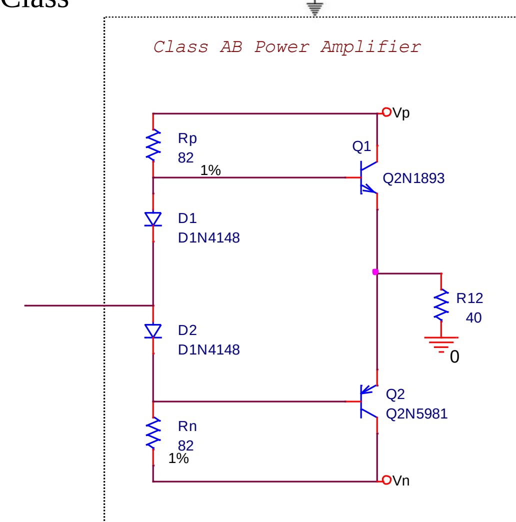
As the input impedance is extremely high, the unity gain buffer (voltage follower) can be used to provide a large power gain as the extra power comes from the op-amps supply rails and through the op-amps output to the load and not directly from the input. However, in most real unity gain buffer circuits there are leakage currents and parasitic capacitances present so a low value (typically 1kΩ) resistor is required in the feedback loop to help reduce the effects of these leakage currents providing stability especially if the operational amplifier is of a current feedback type.

2.2.4 Power Amplifier



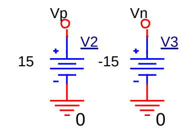
The purpose of any amplifier is to produce an output which follows the characteristics of the input signal but is sufficiently large enough to supply the needs of the load connected to it.

One way to produce an amplifier with the high efficiency output of the Class B configuration along with the low distortion of the Class A configuration is to create an amplifier circuit which is a combination of the previous two classes resulting in a new type of amplifier circuit called a *Class AB Amplifier*. Then the Class AB amplifier output stage combines the advantages of the Class A amplifier and the Class B amplifier while minimising the problems of low efficiency and distortion associated with them.



The class AB is a good compromise between class A and class B in terms of efficiency and linearity having the efficiency reaching about 50% to 60%. The class A, B and AB amplifiers are called as **linear amplifiers** because the output signal amplitude and phase are linearly related to the input signal amplitude and phase.

I used the 1N4148 diode. This diode has a forward-voltage drop of 0.7 and a peak inverse voltage of 100 V, and can carry a maximum of 200 mA of current.



Now, in our case, we will determine the current to the ouput resistance:

$$I_0 = \frac{V_0}{R_0} \qquad\qquad V_D = 0.7V$$

$$I_0 min = {V_{0min}}/{R_0} = \frac{5V}{40\Omega} = 0.125A$$

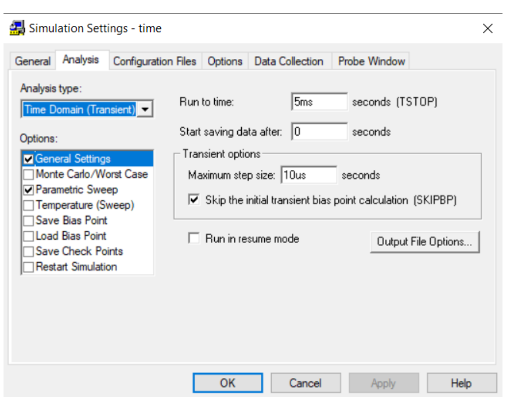
$$I_0 max = {V_{0max}}/{R_0} = \frac{7V}{40\Omega} = 0.175A$$

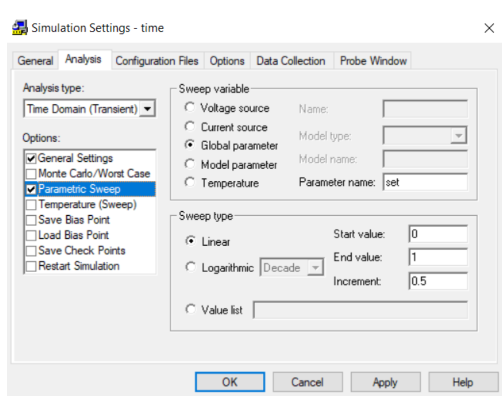
$$R_n = R_p = \frac{V_{CC} - v_D}{I_0} = \frac{15 - 0.7}{0.175} = 81.7\Omega \cong 82\Omega$$

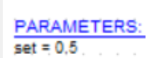
3. SIMULATIONS

3.1. Time Domain (Transient) with Parametric Sweep

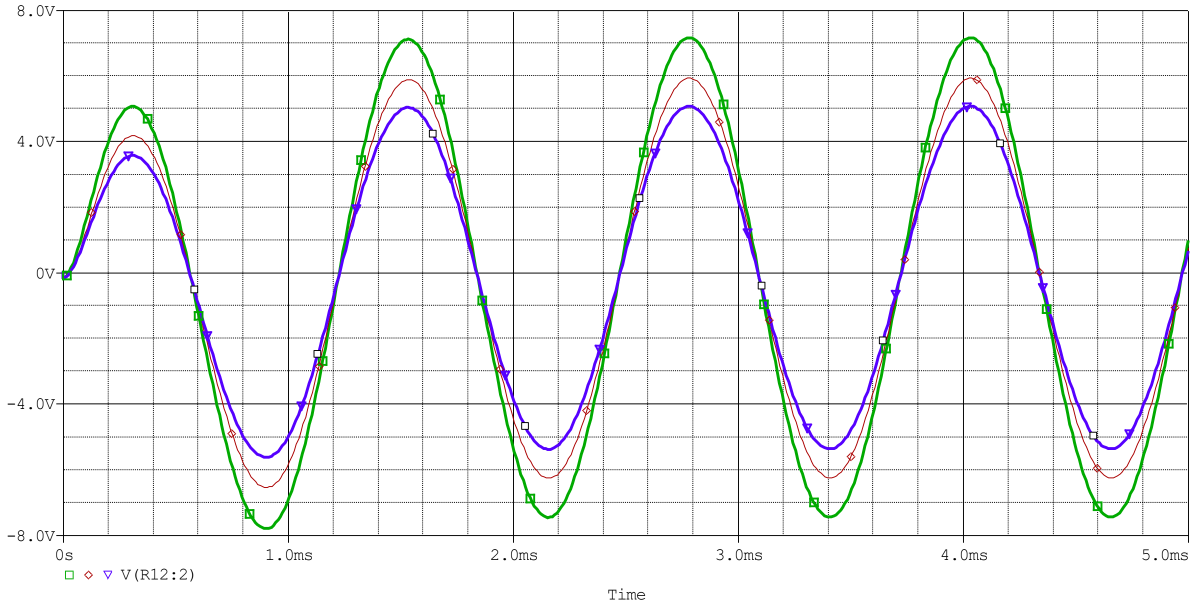
Parametric analyses perform multiple iterations of the same time domain analysis while sweeps a global parameter, a simulation model parameter, a component value, or the temperature. The effect is the same as the same analysis is run several times, a run for each value of the swept variable. Thus, the parametric analysis determines the circuit response at different analyses specified by the user when a parameter is swept.





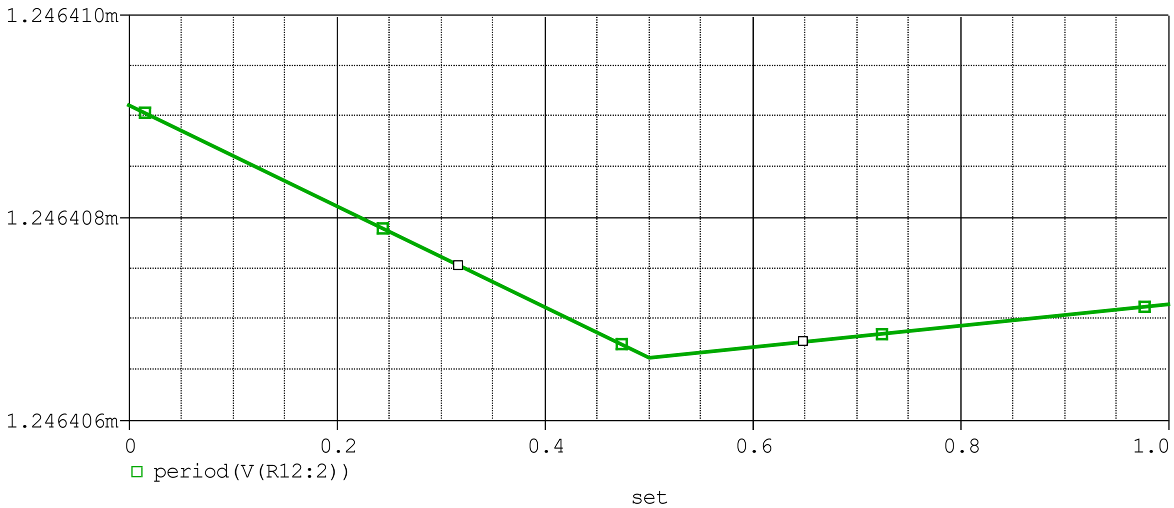


The set *run to time* to 5ms so we can see 4 periods from our signal (f=800 so T=1/800=1.25ms.



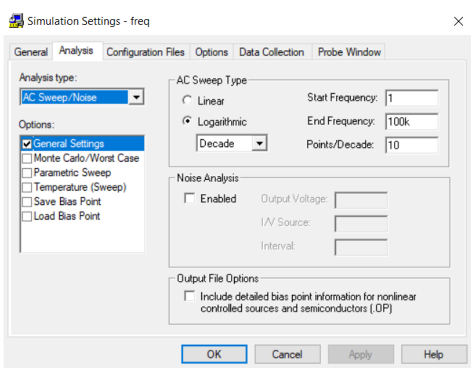
We can see here that our output amplitude can be anywhere **between 5V and 7V** depending on the setting of the potentiometer R9.

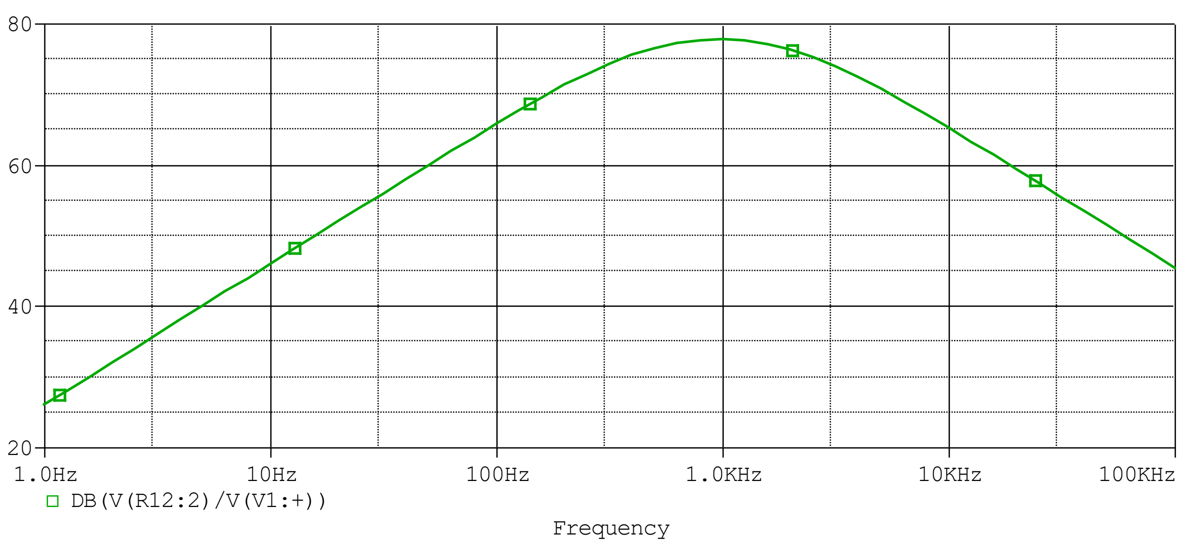
Using the period function we got:



3.2. AC Sweep

The frequency response analysis calculates all of the AC node voltages and branch currents over a swept range of frequencies. The output of this analysis are the values for the amplitude of nodevoltages and device currents, and also, the relative phase angles of the node voltages and device currents. By “frequency response”, it actually means “small-signal frequency response”, where the analysis is done with the assumption that the input signals are small enough to minimize non-linear effects. Novice users of PSpice often confuse frequency response with “transient response”. They relate frequency response to a lab-bench setup that sweeps the input of their circuit, while they look at the output with an oscilloscope.

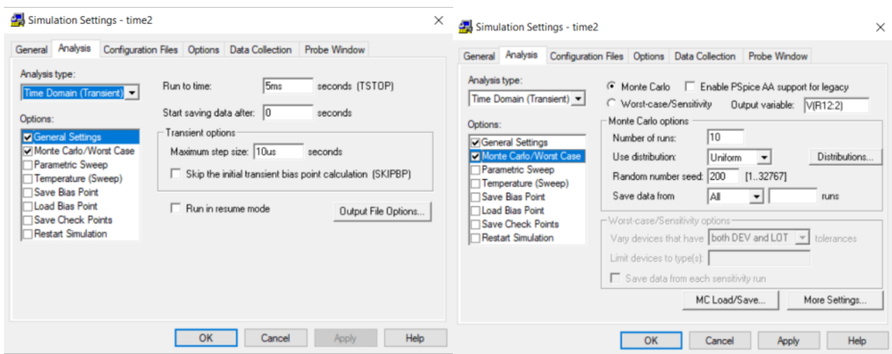


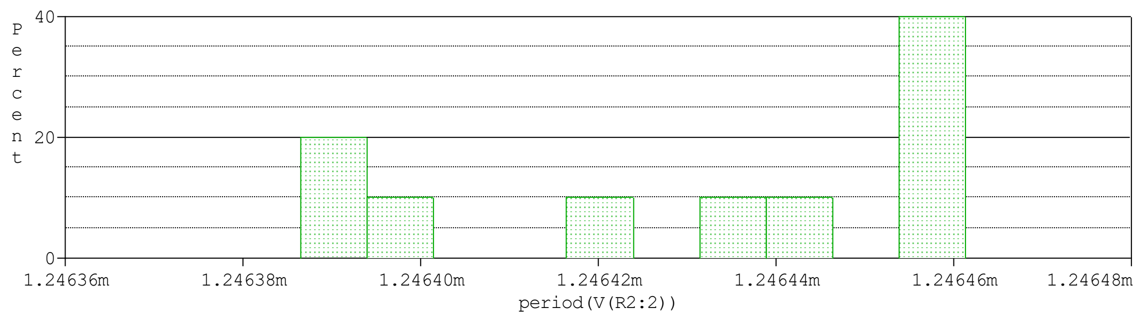


Our required bandwidth goes from 512 to 2048 Hz. To measure the badwidth we have to look at -3dB and +3dB and see the measurements we have there.

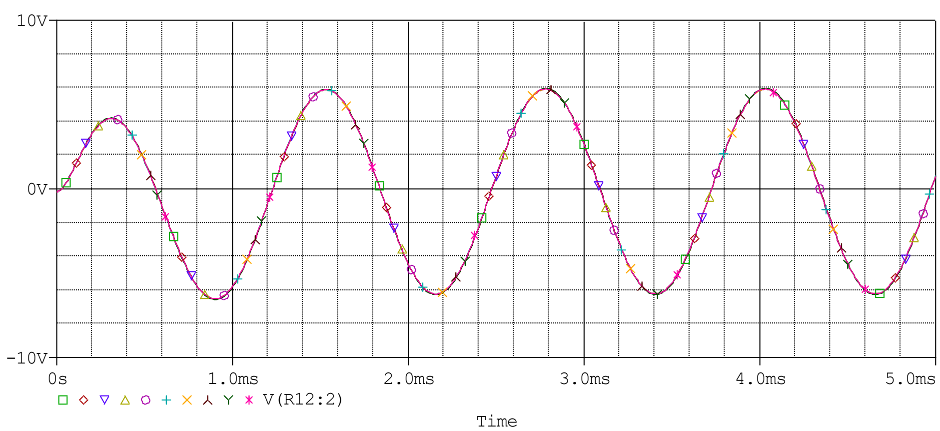
3.3. Time Domain (Transient) with Monte Carlo

The Monte-Carlo analysis is the best way of analyzing a circuit in statistical terms, to see how the circuit behaves at components values variation. Monte Carlo determines, statistically, the circuit behavior when the components values are changed in their tolerance domain. This analysis calculates also the productivitythat can be used for statistical analyses of the production. Monte Carlo is very useful to have a real close imagine on the circuit operation in terms of mass production when the entire range of components used in the assembly line have tolerance.



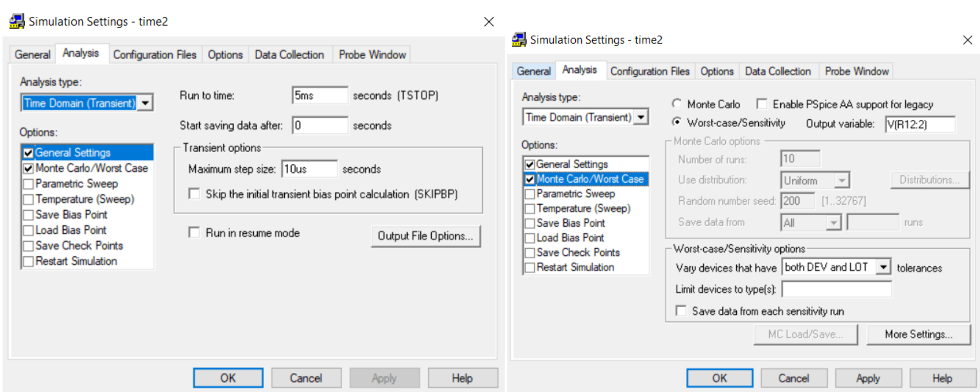


n samples	= 10	minimum	= 0.00124639	maximum	= 0.00124646
n divisions	= 10	10th %ile	= 0.00124639	3*sigma	= 8.9693e-008
mean	= 0.00124643	median	= 0.00124644		
sigma	= 2.98977e-008	90th %ile	= 0.00124646		



3.4. Time Domain (Transient) with Worst Case

As the Monte-Carlo, Worst-Case determines multiple runs of selected primary analysis. Worst-Case varies only one parameter at every run. It allows to PSPICE to calculate the output signal sensitivity for each parameter. One the sensitivities are known, the simulation runs again varying all the parameters to determine the worst case. Sensitivity/Worst-Case is run using parameters models variation specified by the field DEV and LOT from each simulation model, .MODEL. Other specification of the Worst-Case control the results generated by the analysis. As a result, the number of runs of theprimary analysis determined by the Worst-Case analysis will be equal to the number of components that have tolerance defined in the model plus a unit.




```
****     UPDATED MODEL PARAMETERS         TEMPERATURE =   27.000 DEG C

                   WORST CASE ALL DEVICES

******************************************************************************


Device        MODEL        PARAMETER    NEW VALUE
C_C2          C_C2         C               1.01           (Increased)
C_C1          C_C1         C                .99           (Decreased)
R_R3          R_R3         R               1.001          (Increased)
R_R4          R_R4         R                .999          (Decreased)
R_R6          R_R6         R                .999          (Decreased)
R_R5          R_R5         R               1.001          (Increased)
R_R7          R_R7         R               1.001          (Increased)
R_R12         R_R12        R               1.01           (Increased)
R_R13         R_R13        R               1              (Unchanged)
R_Rn          R_Rn         R               1.01           (Increased)
R_Rp          R_Rp         R                .99           (Decreased)
R_R1          R_R1         R                .999          (Decreased)
R_R2          R_R2         R               1.001          (Increased)

**** 05/27/21 09:52:41 ******* PSpice Lite (March 2016) ******* ID# 10813 ****

 ** Profile: "SCHEMATIC1-time2"  [ c:\users\ioana ciobu\documents\.an ii\sem 2\.cad\audioamp2-PSpiceFiles\SCHEMATIC1\time2.sim ]


 ****     SORTED DEVIATIONS OF V(N49534)   TEMPERATURE =   27.000 DEG C

                   WORST CASE SUMMARY

******************************************************************************


Mean Deviation =     .0603
Sigma          =    0

 RUN                        MAX DEVIATION FROM NOMINAL

WORST CASE ALL DEVICES
                             .0603  higher  at T =  922.8600E-06
                            (  99.072% of Nominal)


            JOB CONCLUDED
```

Bill of Materials

Item	Quantity	Part/Value	Manufacturer	Vendor
1	1	10k	Vishay	Digi-Key
2	1	10k	Vishay	Digi-Key
3	4	1k	Vishay	Digi-Key
4	1	100k	Vishay	Digi-Key
5	1	82k	Vishay	Digi-Key
6	1	25k	Vishay	Digi-Key
7	1	40	Vishay	Digi-Key
8	1	33n	Vishay	Digi-Key
9	1	82n	Vishay	Digi-Key
10	2	D1N4148	Vishay	Digi-Key
11	1	Q2N1893		Digi-Key
12	1	Q2N5981		Digi-Key
13	5	UA741	STMicroelectronics	Digi-Key

Conclusion

In conclusion, we managed to make an audio amplifier with the required tasks, combining different information that we accumulated during the semester.

Using filters, voltage amplifiers, power amplifiers and managing to combine them to get what we want we've learnt how we could implement in the real world an audio amplifier.

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The following are standard capacitor values. Values below 1 uF are generally available with a 5 or 10 percent tolerance. Values over 1 uF are generally available with a 10 or 20 percent tolerance. Values are in Farads with p = pico, n = nano, u = micro, and m = milli.

	10p	100p	1.0n	10n	100n	1.0u	10u	100u	1.0m	10m
	12p	120p	1.2n	12n	120n	1.2u				
	15p	150p	1.5n	15n	150n	1.5u	15u	150u	1.5m	15m
	18p	180p	1.8n	18n	180n	1.8u				
2.2p	22p	220p	2.2n	22n	220n	2.2u	22u	220u	2.2m	22m
	27p	270p	2.7n	27n	270n	2.7u				
3.3p	33p	330p	3.3n	33n	330n	3.3u	33u	330u	3.3m	33m
	39p	390p	3.9n	39n	390n	3.9u				
4.7p	47p	470p	4.7n	47n	470n	4.7u	47u	470u	4.7m	47m
	56p	560p	5.6n	56n	560n	5.6u				
6.8p	68p	680p	6.8n	68n	680n	6.8u	68u	680u	6.8m	68m
	82p	820p	8.2n	82n	820n	8.2u				

The following are the standard resistor values available in carbon film with a 2 or 5 percent tolerance. Values are in Ohms with K = 1,000 and M = 1,000,000.

1.0	10	100	1.0K	10K	100K	1.0M	10M
1.1	11	110	1.1K	11K	110K	1.1M	11M
1.2	12	120	1.2K	12K	120K	1.2M	12M
1.3	13	130	1.3K	13K	130K	1.3M	13M
1.5	15	150	1.5K	15K	150K	1.5M	15M
1.6	16	160	1.6K	16K	160K	1.6M	16M
1.8	18	180	1.8K	18K	180K	1.8M	18M
2.0	20	200	2.0K	20K	200K	2.0M	20M
2.2	22	220	2.2K	22K	220K	2.2M	22M
2.4	24	240	2.4K	24K	240K	2.4M	
2.7	27	270	2.7K	27K	270K	2.7M	
3.0	30	300	3.0K	30K	300K	3.0M	
3.3	33	330	3.3K	33K	330K	3.3M	
3.6	36	360	3.6K	36K	360K	3.6M	
3.9	39	390	3.9K	39K	390K	3.9M	
4.3	43	430	4.3K	43K	430K	4.3M	
4.7	47	470	4.7K	47K	470K	4.7M	
5.1	51	510	5.1K	51K	510K	5.1M	
5.6	56	560	5.6K	56K	560K	5.6M	
6.2	62	620	6.2K	62K	620K	6.2M	
6.8	68	680	6.8K	68K	680K	6.8M	
7.5	75	750	7.5K	75K	750K	7.5M	
8.2	82	820	8.2K	82K	820K	8.2M	
9.1	91	910	9.1K	91K	910K	9.1M	

UA741

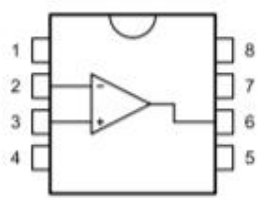
General-purpose single operational amplifier

Datasheet - production data

N
DIP8
(plastic package)

D
SO8
(plastic micropackage)

Pin connections
(top view)



1 - Offset null 1
2 - Inverting input
3 - Non-inverting input
4 - V_{CC}^-
5 - Offset null 2
6 - Output
7 - V_{CC}^+
8 - N.C.

Features

- Large input voltage range
- No latch-up
- High gain
- Short-circuit protection
- No frequency compensation required
- Same pin configuration as the UA709

Applications

- Summing amplifiers
- Voltage followers
- Integrators
- Active filters
- Function generators

Description

The UA741 is a high performance monolithic operational amplifier constructed on a single silicon chip. It is intended for a wide range of analog applications.

The high gain and wide range of operating voltages provide superior performances in integrators, summing amplifiers and general feedback applications. The internal compensation network (6 dB/octave) ensures stability in closed-loop circuits.

2 Absolute maximum ratings and operating conditions

Table 1. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Supply voltage	±22	V
V_{id}	Differential input voltage	±30	
V_i	Input voltage	±15	
	Output short-circuit duration	Infinite	
R_{thja}	Thermal resistance junction to ambient DIP8 SO8	 85 125	°C/W
R_{thjc}	Thermal resistance junction to case DIP8 SO8	 41 40	
ESD	HBM: human body model(1) DIP package SO package	 500 400	V
	MM: machine model(2)	100	
	CDM: charged device model(3)	1.5	kV
T_{stg}	Storage temperature range	-65 to +150	°C

1. Human body model: a 100 pF capacitor is charged to the specified voltage, then discharged through a 1.5kΩ resistor between two pins of the device. This is done for all couples of connected pin combinations while the other pins are floating.
2. Machine model: a 200 pF capacitor is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5 Ω). This is done for all couples of connected pin combinations while the other pins are floating.
3. Charged device model: all pins and the package are charged together to the specified voltage and then discharged directly to the ground through only one pin. This is done for all pins.

Table 2. Operating conditions

Symbol	Parameter	UA741I	UA741C	Unit
V_{CC}	Supply voltage	5 to 40		V
V_{icm}	Common mode input voltage range	±12		
T_{oper}	Operating free air temperature range	-40 to +105	0 to +70	°C

3 Electrical characteristics

Table 3. Electrical characteristics at V_{CC} = ±15 V, T_{amb} = 25 °C (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input offset voltage ($R_s \leq 10$ kΩ) T_{amb} = +25 °C $T_{min} \leq T_{amb} \leq T_{max}$		1	5 6	mV
I_{io}	Input offset current T_{amb} = +25 °C $T_{min} \leq T_{amb} \leq T_{max}$		2	30 70	nA
I_{ib}	Input bias current T_{amb} = +25 °C $T_{min} \leq T_{amb} \leq T_{max}$		10	100 200	nA
A_{vd}	Large signal voltage gain (V_o = ±10 V, R_L = 2 kΩ) T_{amb} = +25 °C $T_{min} \leq T_{amb} \leq T_{max}$	50 25	200		V/mV
SVR	Supply voltage rejection ratio ($R_s \leq 10$ kΩ) T_{amb} = +25 °C $T_{min} \leq T_{amb} \leq T_{max}$	77 77	90		dB
I_{CC}	Supply current, no load T_{amb} = +25 °C $T_{min} \leq T_{amb} \leq T_{max}$		1.7	2.8 3.3	mA
V_{icm}	Input common mode voltage range T_{amb} = +25 °C $T_{min} \leq T_{amb} \leq T_{max}$	±12 ±12			V
CMR	Common mode rejection ratio ($R_S \leq 10$ kΩ) T_{amb} = +25 °C $T_{min} \leq T_{amb} \leq T_{max}$	70 70	90		dB
I_{OS}	Output short circuit current	10	25	40	mA
$\pm V_{opp}$	Output voltage swing T_{amb} = +25 °C, R_L = 10 kΩ R_L = 2 kΩ $T_{min} \leq T_{amb} \leq T_{max}$, R_L = 10 kΩ R_L = 2 kΩ	12 10 12 10	14 13		V
SR	Slew rate V_i = ±10 V, R_L = 2 kΩ, C_L = 100 pF, unity gain	0.25	0.5		V/μs
t_r	Rise time V_i = ±20 mV, R_L = 2 kΩ, C_L = 100 pF, unity gain		0.3		μs
K_{ov}	Overshoot V_i = 20 mV, R_L = 2 kΩ, C_L = 100 pF, unity gain		5		%
R_i	Input resistance	0.3	2		MΩ

Table 3. Electrical characteristics at V_{CC} = ±15 V, T_{amb} = 25 °C (unless otherwise specified) (continued)

Symbol	Parameter	Min.	Typ.	Max.	Unit
GBP	Gain bandwidth product V_i = 10 mV, R_L = 2 kΩ, C_L = 100 pF, f =100 kHz	0.7	1		MHz
THD	Total harmonic distortion f = 1 kHz, A_v = 20 dB, R_L = 2 kΩ, V_o = 2 V_{pp}, C_L = 100 pF, T_{amb} = +25° C		0.06		%
e_n	Equivalent input noise voltage f = 1 kHz, R_s = 100 Ω		23		$\frac{nV}{\sqrt{Hz}}$
∅m	Phase margin		50		Degree

Small Signal Fast Switching Diodes

FEATURES

- Silicon epitaxial planar diode
- Electrically equivalent diodes: 1N4148 - 1N914
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

RoHS
COMPLIANT
HALOGEN
FREE

APPLICATIONS

- Extreme fast switches

DESIGN SUPPORT TOOLS click logo to get started

3D Models Available

MECHANICAL DATA

Case: DO-35 (DO-204AH)

Weight: approx. 105 mg

Cathode band color: black

Packaging codes / options:

TR/10K per 13" reel (52 mm tape), 50K/box

TAP/10K per ammopack (52 mm tape), 50K/box

PARTS TABLE

PART	ORDERING CODE	TYPE MARKING	CIRCUIT CONFIGURATION	REMARKS
1N4148	1N4148-TAP or 1N4148TR	V4148	Single	Tape and reel / ammopack

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)

PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
Repetitive peak reverse voltage		V_{RRM}	100	V
Reverse voltage		V_R	75	V
Peak forward surge current	t_p = 1 µs	I_{FSM}	2	A
Repetitive peak forward current		I_{FRM}	500	mA
Forward continuous current		I_F	300	mA
Average forward current	V_R = 0	$I_{F(AV)}$	150	mA
Power dissipation	l = 4 mm, T_L = 45 °C	P_{tot}	440	mW
	l = 4 mm, T_L ≤ 25 °C	P_{tot}	500	mW

THERMAL CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)

PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
Thermal resistance junction to ambient air	l = 4 mm, T_L = constant	R_{thJA}	350	K/W
Junction temperature		T_j	175	°C
Storage temperature range		T_{stg}	-65 to +150	°C

ELECTRICAL CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)						
PARAMETER	TEST CONDITION	SYMBOL	MIN.	TYP.	MAX.	UNIT
Forward voltage	I_F = 10 mA	V_F			1	V
Reverse current	V_R = 20 V	I_R			25	nA
	V_R = 20 V, T_j = 150 °C	I_R			50	µA
	V_R = 75 V	I_R			5	µA
Breakdown voltage	I_R = 100 µA, t_p/T = 0.01, t_p = 0.3 ms	$V_{(BR)}$	100			V
Diode capacitance	V_R = 0 V, f = 1 MHz, V_{HF} = 50 mV	C_D			4	pF
Rectification efficiency	V_{HF} = 2 V, f = 100 MHz	η_r	45			%
Reverse recovery time	$I_F = I_R$ = 10 mA, i_R = 1 mA	t_{rr}			8	ns
	I_F = 10 mA, V_R = 6 V, i_R = 0.1 x I_R, R_L = 100 Ω	t_{rr}			4	ns

TYPICAL CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)

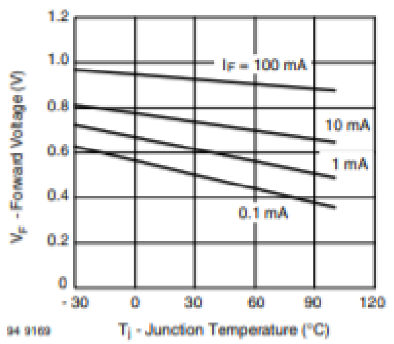


Fig. 1 - Forward Voltage vs. Junction Temperature

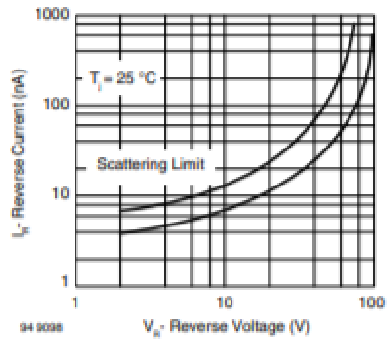


Fig. 3 - Reverse Current vs. Reverse Voltage

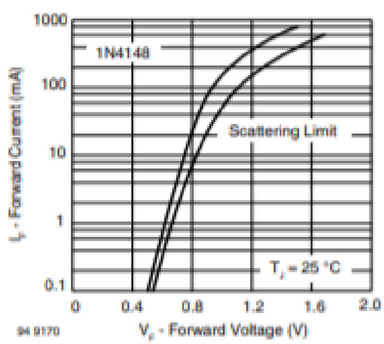


Fig. 2 - Forward Current vs. Forward Voltage