



Elektronika ***uvodno predavanje***

Prof.dr.Zoran Mijanović



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- 1959. rođen u Ljubljani
- Osnovna škola “Maksim Gorki” u Titogradu (Luča, savezno takmičenje 1972. Novi Sad)
- 1977. završio Gimnaziju u Titogradu (Luča)
- 1981. diplomirao na ETF-u Titograd (9,62)
- 1981-1983 u Institutu “Mihailo Pupin”
- 1983. magistrirao na ETF Beograd
- 1984. asistent na ETF Titograd
- 1989. doktorirao na ETF Beograd
- 2000. redovni profesor
- Osnivač nekoliko firmi
- Saradnja sa privredom

Ciljevi izučavanja predmeta



- Upoznati analogna elektronska kola
- Naučiti metode analize analognih kola:
 - idealni operacioni pojačavač
 - frekvencijska analiza, filteri
 - povratna sprega, stabilnost kola
 - termički račun, iskorišćenje snage
- Upoznati i analizirati prekidačka kola snage
- Pratiti savremene tehnike i tehnologije

Metod nastave i savladavanja gradiva



- Predavanja
- Računske vježbe
- Rad na računaru
- Laboratorijske vježbe
- Učenje i samostalan rad
- Seminarski rad
- Konsultacije.

Ishodi učenja



Nakon što student položi ovaj ispit biće u mogućnosti da:

- Analizira kola sa VFB i CFB operacionim pojačavačima;
- Izvrši frekvencijsku analizu pojačavača, aktivnih i pasivnih filtera;
- Odredi uslove oscilovanja datog kola i nađe učestanost oscilovanja;
- Dimenzioniše kolo za automatsku regulaciju amplitude oscilovanja;
- Konstruiše oscilator u 3 tačke;
- Analizira stabilnost kola sa povratnom spregom;
- Prepozna osnovne konfiguracije PLL-a i odredi osnovne parametre PLL-a;
- Termički analizira kola sa tranzistorima snage i pojačavačima snage;
- Proračuna osnovne parametre linearnog stabilizatora (ulazne i izlazne napone, strujni kapacitet);
- Prepozna osnovne konfiguracije prekidačkih izvora napajanja i nađe vezu između vremena prekidanja i izlaznog napona.

Literatura



- Univerzitetski udžbenici sa ETF Beograd, Zagreb, Sarajevo, Banja Luka, ...
- Npr: Analogna integrisana kola – Slavoljub Marjanović – ETF Beograd
- Microelectronic circuits - Sedra i Smith
- www.wikipedia.org
- <http://sts.etf.ac.me:3000/elektronika>



Oblici provjere znanja i ocjenjivanje



- Laboratorijske vježbe 10 poena,
- Domaći zadaci 5 poena,
- Seminarski rad do 10 poena, i obavezan je za najvišu ocjenu,
- Kolokvijum 30 poena,
- Završni ispit 45 poena,
- Prelazna ocjena se dobija ako se kumulativno sakupi najmanje 51 poen.

Seminarski radovi – vrste:



- Naći na Internetu softverski alat za Elektroniku, ocijeniti ga i napraviti uputstvo za upotrebu
- Napraviti članak za www.wikipedia.org
- Napraviti neko elektronsko kolo, analizirati ga i izmjeriti karakteristike
- Predložiti ideju za poboljšanje nastave



Neke ideje za seminarski rad

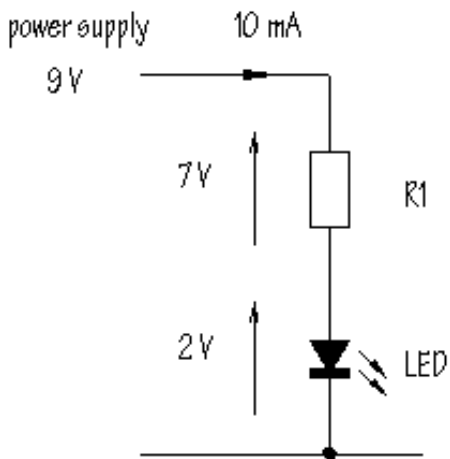


- Ovladati nekim simulacionim programom za analizu elektronskih kola poput PSPICE, TINA-TI, MULTISIM, QUICS, ...
- Ovladati nekim programom za termički proračun i dizajniranje hladnjaka poput Sauna, FloTHERM, ...
- Ovladati nekim programom za generisanje funkcija poput SoundArb, Matlab, SignalGen, T-TTG, ...
- Ovladati nekim programom za snimanje vremenskih dijagrama poput Soundcard Oscilloscope, Daqarta, Matlab, ...
- Ovladati nekim programom za proračun analognih filtera poput WeBench, FilterPro, microcap, Okawa Filter Design and Analysis, ...
- Ovladati nekim programom za dizajn induktiviteta poput irondemo, tor-demo, ...

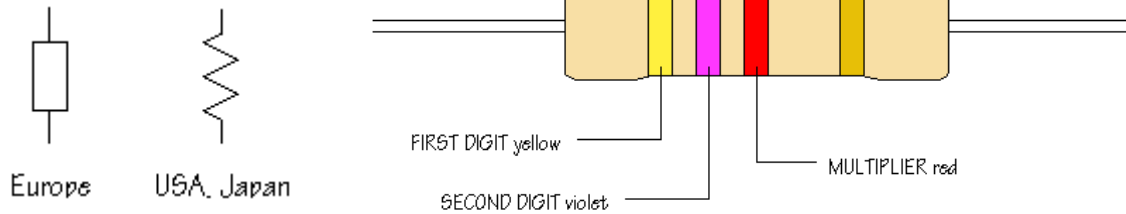
Pregled osnovnih pojmova iz elektronike (podsjećanje)



- Otpornici
- Kondenzatori
- Pojačavači
- Modeli za velike i male signale



Otpornik



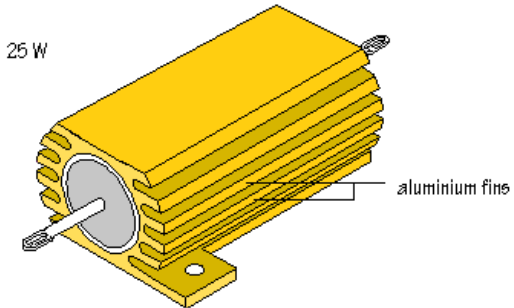
0.25 W

0.5 W

1 W

2 W

25 W



- Otpornost Ω (kod idealnog otpornika ovo je jedina karakteristika – drugih nema)
- Snaga W , tolerancija $\%$, temperaturni koeficijent $\%/^{\circ}C$, gabariti $mm \times mm \times mm$, cijena EUR
- Induktivnost H , kapacitivnost F , zračenje, način postavljanja, MTBF h , preopteretivost $\%$, izdržljivost na ubrzanja i vibracije g



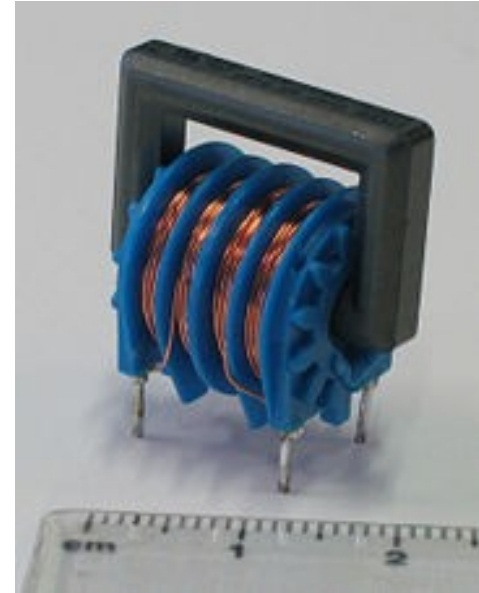
Kondenzator



- Kapacitivnost F (jedina karakteristika kod idealnog kondenzatora)
- Probojni napon V , tangens gubitaka δ , tolerancija $\%$, temperaturni koeficijent $\%/^{\circ}C$, gabariti $mm \times mm \times mm$, cijena EUR
- Bipolarnost, vremenska konstanta s , vrsta izolacije, induktivnost H , otpornost Ω , zračenje, način postavljanja, MTBF h , ispitni napon V , izdržljivost na ubrzanja i vibracije g

Induktivitet (prigušnica)

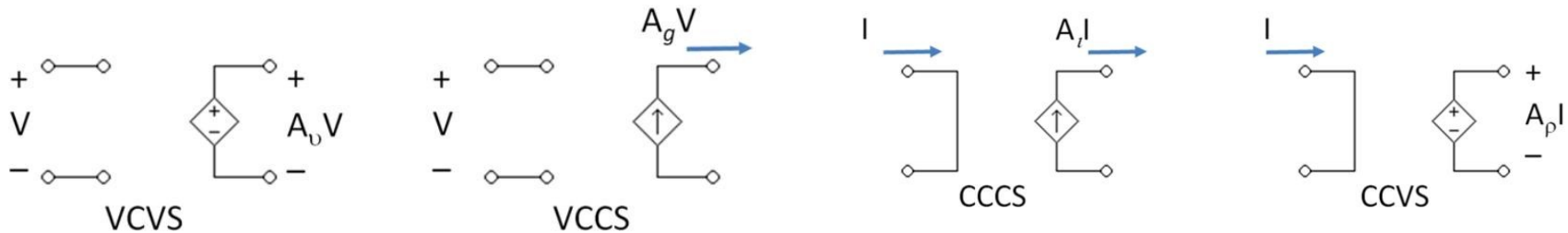
<http://en.wikipedia.org/wiki/Inductor#Formulae>



- Idealno samo induktivnost H
- Dozvoljena struja A , faktor dobrote Q , tolerancija $\%$, temperaturni koeficijent $\%/^{\circ}C$, gabariti $mm \times mm \times mm$, cijena EUR
- Otpornost Ω , kapacitivnost F , zračenje, način postavljanja, MTBF h , ispitni napon V , izdržljivost na ubrzanja i vibracije g



Idealni pojačavač



- Karakteriše se **vrstom** i **iznosom** pojačanja
- Vrste pojačanja:
 - Naponsko A_v (napon u napon)
 - Transadmitansno A_g (napon u struju)
 - Strujno A_i (struja u struju)
 - Transimpedansno A_r (struja u napon)
- <http://en.wikipedia.org/wiki/Amplifier>
- Ulazne/izlazne impedanse su ili beskonačno ili nula

Realni pojačavač se opisuje sa znatno više parametara



National Semiconductor May 1999

LM124/LM224/LM324/LM291 Low Power Quad Operatio

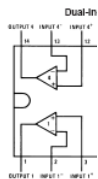
General Description

The LM124 series consists of four independent, high gain internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Unique Characteristics

- In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage.
- The unity gain cross frequency is temperature compensated.
- The input bias current is also temperature compensated.

Connection Diagram



Absolute Maximum Ratings (Note 12)

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

Supply Voltage, V^+
 Differential Input Voltage
 Input Voltage
 Input Current
 $(V^+ < -0.3V)$ (Note 5)
 Power Dissipation (Note 4)
 Molded DIP
 Cavity DIP
 Small Outline Package
 Output Short-Circuit to GND (One Amplifier) (Note 5)
 $V^+ \leq 15V$ and $T_A = 25^\circ C$
 Operating Temperature Range
 LM324/LM324A
 LM224/LM224A
 LM124/LM124A
 Storage Temperature Range
 Lead Temperature (Soldering, 10 seconds)
 Soldering Information
 Dual-In-Line Package
 Soldering (10 seconds)
 Small Outline Package
 Vapor Phase (60 seconds)
 Infrared (15 seconds)
 See AN-450 Surface Mounting Methods and Their Devices.
 ESD Tolerance (Note 13)

Electrical Characteristics

$V^+ = +5.0V$, (Note 7), unless otherwise stated

Parameter	Conditions
Input Offset Voltage (Note 8) $T_A = 25^\circ C$	
Input Bias Current (Note 9)	$I_{BIAS} \text{ OF } I_{IN} \text{ @ } V_{CM} = 0V, T_A = 25^\circ C$
Input Offset Current (Note 9)	$I_{OS} \text{ OF } I_{IN} \text{ @ } V_{CM} = 0V, T_A = 25^\circ C$
Input Common-Mode Voltage Range (Note 10)	$V^+ = 30V, (LM2902, V^+ = 28V), T_A = 25^\circ C$
Supply Current	Over Full Temperature Range $R_L = \infty$ On All Op Amps $V^+ = 30V, (LM2902, V^+ = 28V), V^+ = 5V$
Large Signal Voltage Gain	$V^+ = 15V, R_L \geq 2k\Omega, (V_O = 1V \text{ to } 11V), T_A = 25^\circ C$
Common-Mode Rejection Ratio	$DC, V_{CM} = 0V \text{ to } V^+ - 1.5V, T_A = 25^\circ C$

Electrical Characteristics (Continued)

$V^+ = +5.0V$, (Note 7), unless otherwise stated

Parameter	Conditions	LM124A				LM224A				LM324A				Units
		Min	Typ	Max		Min	Typ	Max		Min	Typ	Max		
Power Supply Rejection Ratio	$V^+ = 5V \text{ to } 30V, (LM2902, V^+ = 5V \text{ to } 26V), T_A = 25^\circ C$													
Amplifier-to-Amplifier Coupling (Note 11)	$f = 1 \text{ kHz to } 20 \text{ kHz}, T_A = 25^\circ C$ (Input Referred)													
Output Current	Source $V_{IN}^+ = 1V, V_{IN}^- = 0V, V^+ = 15V, V_O = 2V, T_A = 25^\circ C$													
	Sink $V_{IN}^+ = 1V, V_{IN}^- = 0V, V^+ = 15V, V_O = 2V, T_A = 25^\circ C$													
Short Circuit to Ground (Note 5)	$V^+ = 15V, V_O = 200 \text{ mV}, T_A = 25^\circ C$													
Input Offset Voltage (Note 8)	$R_L = 2k\Omega$													
Input Offset Current (Note 9)	$I_{BIAS} \text{ OF } I_{IN} \text{ @ } V_{CM} = 0V$													
Input Bias Current (Note 9)	$I_{BIAS} \text{ OF } I_{IN} \text{ @ } V_{CM} = 0V$													
Input Common-Mode Voltage Range (Note 10)	$V^+ = +30V, (LM2902, V^+ = 28V)$													
Large Signal Voltage Gain	$V^+ = +15V, (V_O \text{ Swing} = 1V \text{ to } 11V), R_L \geq 2k\Omega$													
Output Voltage Swing	$V_{OH} = 30V, (LM2902, V^+ = 28V), R_L \geq 2k\Omega$													
	$V_{OL} = 5V, R_L = 10k\Omega$													
Output Current	Source $V_{IN}^+ = 2V, V_{IN}^- = 0V, V^+ = 15V, V_O = 2V, T_A = 25^\circ C$													
	Sink $V_{IN}^+ = 2V, V_{IN}^- = 0V, V^+ = 15V, V_O = 2V, T_A = 25^\circ C$													

Electrical Characteristics

$V^+ = +5.0V$, (Note 7), unless otherwise stated

Parameter	Conditions
Input Offset Voltage (Note 8) $T_A = 25^\circ C$	
Input Bias Current (Note 9)	$I_{BIAS} \text{ OF } I_{IN} \text{ @ } V_{CM} = 0V, T_A = 25^\circ C$
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Input Common-Mode Voltage Range (Note 10)	$V^+ = 30V, (LM2902, V^+ = 28V), T_A = 25^\circ C$
Supply Current	Over Full Temperature Range $R_L = \infty$ On All Op Amps $V^+ = 30V, (LM2902, V^+ = 28V), V^+ = 5V$
Large Signal Voltage Gain	$V^+ = 15V, R_L \geq 2k\Omega, (V_O = 1V \text{ to } 11V), T_A = 25^\circ C$

Note 4: For operating at high temperatures, the LM324/LM224A/LM2902 must be derated by a factor of 80°C/W which applies for the device soldered to a printed circuit board, operating in a rated base to a +150°C maximum junction temperature. The dissipation in the lead of a free potted or surface of a device is not to exceed the power which is dissipated in the integrated circuit.

Note 5: Short circuits from the output to V^+ can cause excessive heating and eventual destruction current is approximately 40 mA independent of the magnitude of V^+ . All values of supply voltage dissipation ratings and cause eventual destruction. Destructive dissipation can result from an input common-mode voltage at any of the input leads to drive a saturation becoming forward biased and thereby acting as input diode clamps. In addition to this IC trip, this transistor action can cause the output voltage of the op-amp to go to the V^+ or V^- if an input is driven negative. This is not destructive and normal output states will be established greater than -0.3V (at 25°C).

Note 6: These specifications are limited to -55°C to +125°C for the LM124/LM124A, with $T_A \leq +85^\circ C$. The LM324/LM224A temperature specifications are limited to 0°C to +170°C.

Note 7: $V_O = 1.4V, R_L = 2k\Omega$ with V^+ from 5V to 30V, and over the full input common-mode range.

Note 8: The direction of the input current is out of the IC due to the PNP input stage. This current is leading change state on the input line.

Note 9: The input common-mode voltage of either input signal voltage should not be above common-mode voltage range $V^+ - 1.5V$ (at 25°C), but either or both inputs can go to +52V V^+ .

Note 11: Due to proximity of external components, insure that coupling is not originating via a detected as this type of capacitance increases at higher frequencies.

Note 12: Refer to RETS/DIAK for LM124A military specifications and refer to RETS124K for

Electrical Characteristics (Continued)

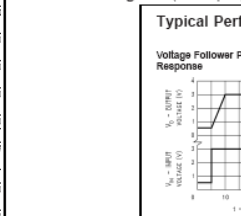
$V^+ = +5.0V$, (Note 7), unless otherwise stated

Parameter	Conditions	LM124/LM224				LM324				Units
		Min	Typ	Max		Min	Typ	Max		
Common-Mode Rejection Ratio	$DC, V_{CM} = 0V \text{ to } V^+ - 1.5V, T_A = 25^\circ C$									
Power Supply Rejection Ratio	$V^+ = 5V \text{ to } 30V, (LM2902, V^+ = 5V \text{ to } 26V), T_A = 25^\circ C$									
Amplifier-to-Amplifier Coupling (Note 11)	$f = 1 \text{ kHz to } 20 \text{ kHz}, T_A = 25^\circ C$ (Input Referred)									
Output Current	Source $V_{IN}^+ = 1V, V_{IN}^- = 0V, V^+ = 15V, V_O = 2V, T_A = 25^\circ C$									
	Sink $V_{IN}^+ = 1V, V_{IN}^- = 0V, V^+ = 15V, V_O = 2V, T_A = 25^\circ C$									
Short Circuit to Ground (Note 5)	$V^+ = 15V, V_O = 200 \text{ mV}, T_A = 25^\circ C$									
Input Offset Voltage (Note 8)	$R_L = 2k\Omega$									
Input Offset Current (Note 9)	$I_{BIAS} \text{ OF } I_{IN} \text{ @ } V_{CM} = 0V$									
Input Bias Current (Note 9)	$I_{BIAS} \text{ OF } I_{IN} \text{ @ } V_{CM} = 0V$									
Input Common-Mode Voltage Range (Note 10)	$V^+ = +30V, (LM2902, V^+ = 28V)$									
Large Signal Voltage Gain	$V^+ = +15V, (V_O \text{ Swing} = 1V \text{ to } 11V), R_L \geq 2k\Omega$									
Output Voltage Swing	$V_{OH} = 30V, (LM2902, V^+ = 28V), R_L \geq 2k\Omega$									
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Output Current	Source $V_{IN}^+ = 2V, V_{IN}^- = 0V, V^+ = 15V, V_O = 2V, T_A = 25^\circ C$									
	Sink $V_{IN}^+ = 2V, V_{IN}^- = 0V, V^+ = 15V, V_O = 2V, T_A = 25^\circ C$									

Electrical Characteristics (Continued)

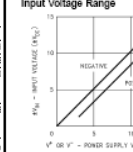
Note 13: Human body model, 1.5 kΩ in series with 100 pF

Schematic Diagram (Each Amplifier)

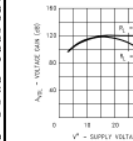


Typical Performance

Input Voltage Range

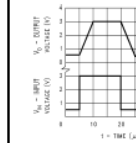


Voltage Gain

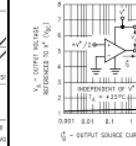


Typical Performance Characteristics (Continued)

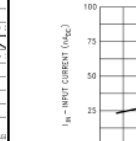
Voltage Follower Pulse Response



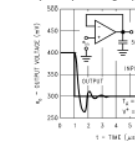
Output Characteristics Current Sourcing



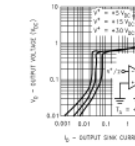
Input Current (LM2902 only)



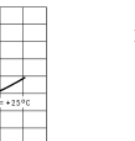
Voltage Follower Pulse Response (Small Signal)



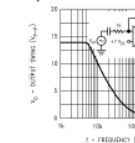
Output Characteristics Current Sinking



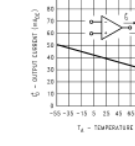
Voltage Gain (LM2902 only)



Large Signal Frequency Response



Current Limiting

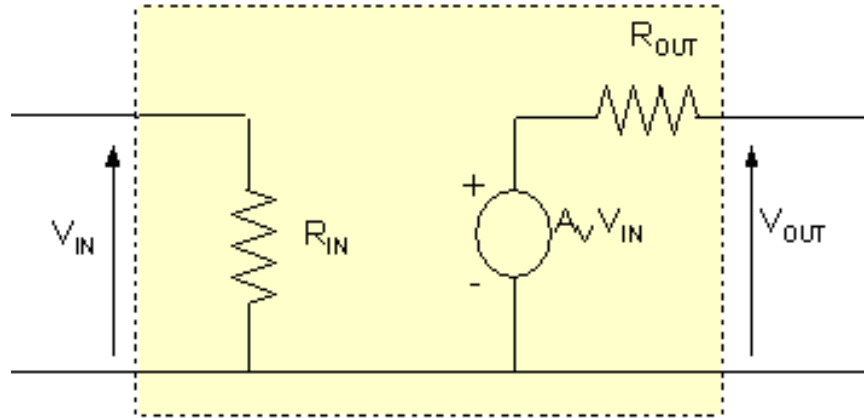


Application Hints

The LM124 series are op amps which operate with only a single power supply voltage, have true differential inputs, and remain in the linear mode with an input common-mode voltage of 0 V_{CM} . These amplifiers operate over a wide range of power supply voltage with little change in performance characteristics. At 25°C amplifier operation is possible down to a minimum supply voltage of 2.3 Vcc.

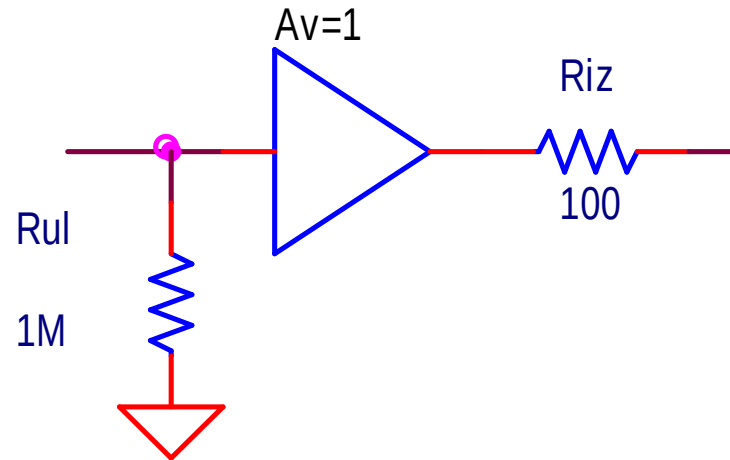
The pinouts of the package have been designed to simplify PC board layouts. Inverting inputs are adjacent to outputs for all of the amplifiers and the outputs have also been placed at the corners of the package (pins 1, 7, 8, and 14). Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a

Realni pojačavač



- Može se predstaviti Teveninovim ili Nortonovim modelom
 - Teveninov model: naponsko pojačanje, ulazna i izlazna impedansa.
 - Nortonov model: strujno pojačanje, R_{ul} i R_{iz}
- Tipične vrijednosti kod realnog naponskog pojačavača su:
 - Naponsko pojačanje A_v (100'000)
 - Ulazna otpornost R_{ul} (Momi)
 - Izlazna otpornost R_{iz} (omi)
- Masa je zajednička za ulaz i izlaz.
- Opseg ulaznog napona i opseg izlaznog napona zavise od napona napajanja pojačavača (od $-V_{ee}+2V$ do $V_{cc}-2V$).

Odnos ulazne/izlazne otpornost je značajan koliko i pojačanje



- Pogledajmo primjer sa jediničnim pojačavačem.
- Na prvi pogled, pojačanje 1 nije korisno, jer je izlazni napon jednak ulaznom.

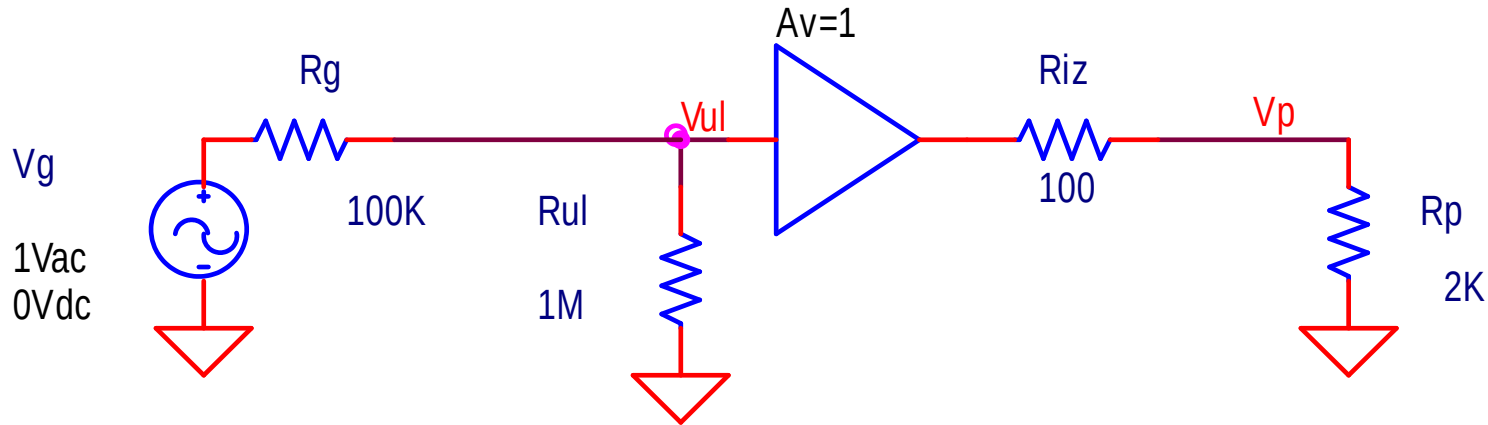


Ali kada imamo visokoomski izvor i niskoomski potrošač...



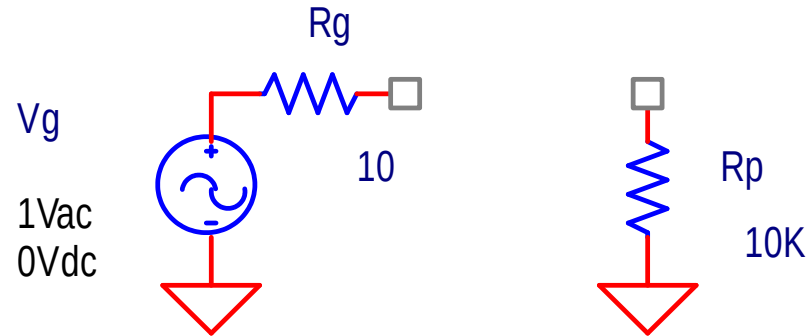
- Direktnim spajanjem izvora i potrošača formira se razdjelnik napona.
- Koliko ćemo dobiti na potrošaču $V_p = ?$ [V]

Umetanjem jediničnog pojačavača dobijamo...



- Dva razdjelnika napona, na ulazu i na izlazu pojačavača
- Prvi razdjelnik pravi na ulazu $V_u = ?$ [V]
- Drugi razdjelnik pravi na potrošaču $V_p = ?$ [V]
- Šta se dobilo umetanjem ovog pojačavača?

Ima situacija kada je ovakav pojačavač štetan



- Kada je $R_g \ll R_p$, umetanjem pojačavač se ne dobija ništa.
- Štaviše, pojačavač unosi šum, izobličenja, limitiranje signala, traži napajanje, ...



Analysis of Amplifier Systems



Simulacija elektronskih kola



- Omogućava provjeru dizajna brzo i jeftino.
- Nije uvijek efikasna (ponekad postoje problemi konvergencije), a ponekad daje neočekivano glupe rezultate.
- Veoma je korisna, ali samo ako znamo šta očekujemo.
- Najpoznatiji simulacioni programi:
 - SPICE
 - Multisim
 - QUCS
- Virtuelni instrumenti (Labview)
 - Mjerenje na realnom i/ili simuliranom sistemu