ELEMEN SISTEM INSTRUMENTASI



Elemen Sistem Instrumentasi

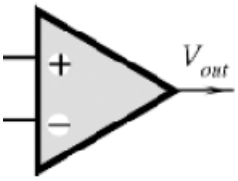
- Sensor
- Signal Conditioning (pengkondisi sinyal)
  - Amplifier
  - Filter
- Signal Processing (pemroses sinyal)
  - Multiplexing
  - Analog – Digital Converter
  - Digital – Analog Converter
- Data Presentation (display)

PENGKONDISI SINYAL - Amplifier

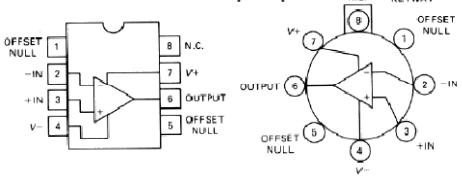
- **Amplifier**
  - Operational Amplifier
  - Instrument Amplifier

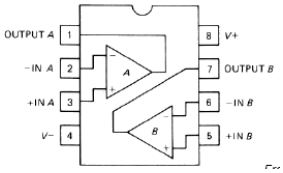
OPERATIONAL AMPLIFIER

- Primary op-amp terminal
  - Inverting input
  - Non-inverting input
  - Output
  - Power supply



Contoh : IC op-amp 741



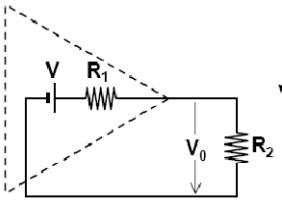


Dual op-amp 1458

Amplifier : Op - Amp

Karakteristik Op-Amp Ideal

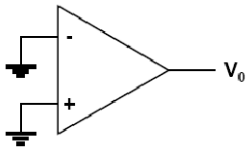
- Infinite open loop voltage gain
  - *Open loop gain* adalah *gain* op-amp tanpa umpan balik
  - Ideal open loop gain : tidak terhingga
- Infinite input impedance
  - Arus input adalah NOL
  - Beberapa *low grade op-amp* memiliki arus input dalam orde mA
- Zero output impedance
  - Beberapa op-amp memiliki *output impedance* sekiat 100 – 200 Ω



$$V_0 = \frac{VR_2}{R_1 + R_2}$$

Amplifier : Op - Amp

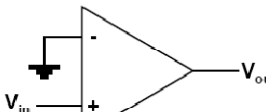
- Zero noise contribution
- Zero DC output offset
  - *Output offset* merupakan tegangan output pada saat kedua input di-ground (nol)



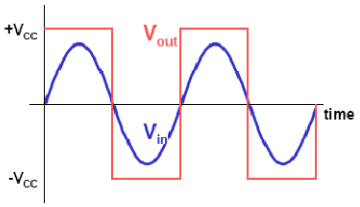
- Infinite bandwidth
- Differential inputs that stick together

Amplifier : Rangkaian Op - Amp

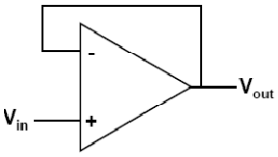
- **Voltage comparator**



$V_{out} = V_{CC}\,\text{sign}(V_{in})$



- **Voltage follower**

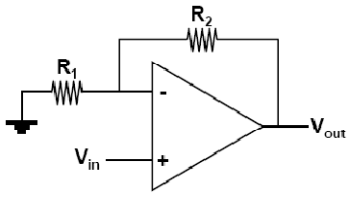


$V_{out} = V_{in}$

SISTEM PENGUKURAN

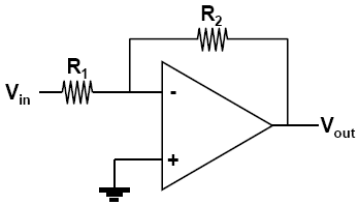
Amplifier : Rangkaian Op - Amp

- Non-inverting amplifier



$$V_{out} = \left(1 + \frac{R_2}{R_1}\right) V_{in}$$

- Inverting amplifier

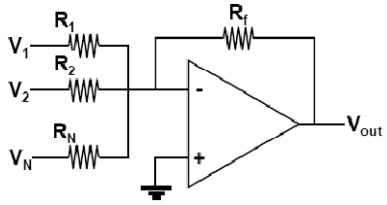


$$V_{out} = -\frac{R_2}{R_1} V_{in}$$

SISTEM PENGUKURAN

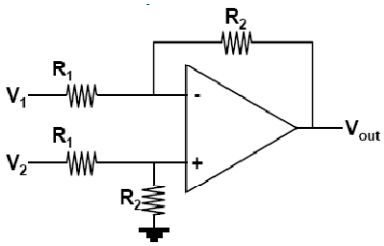
Amplifier : Rangkaian Op - Amp

- Summing amplifier



$$V_{out} = -\left(V_1 \frac{R_f}{R_1} + V_2 \frac{R_f}{R_2} + \cdots + V_N \frac{R_f}{R_N}\right)$$

- Differential amplifier

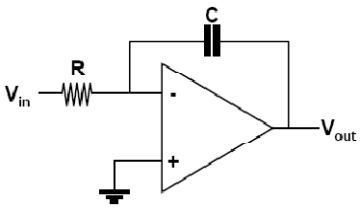


$$V_{out} = \frac{R_2}{R_1}(V_2 - V_1)$$

SISTEM PENGUKURAN

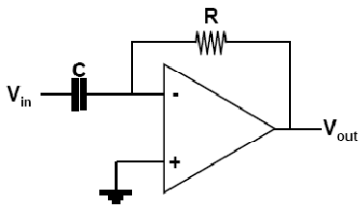
Amplifier : Rangkaian Op - Amp

- Integrating amplifier



$$V_{out} = -\frac{1}{j\omega CR} V_{in} = -\frac{1}{RC}\int V_{in} dt$$

- Differentiating amplifier

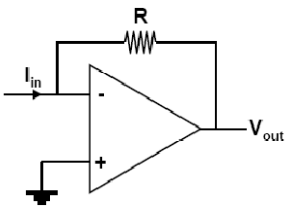


$$V_{out} = -\frac{R}{\frac{1}{j\omega C}} V_{in} = -RC\frac{dV_{in}}{dt}$$

SISTEM PENGUKURAN

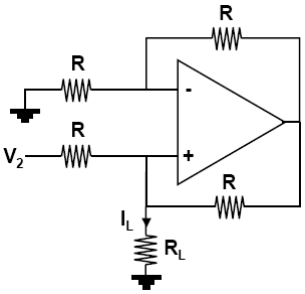
Amplifier : Rangkaian Op - Amp

- Current to Voltage converter



$$V_{out} = -I_{in}R$$

- Voltage to Current converter

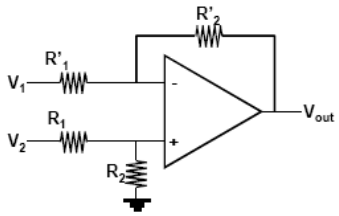


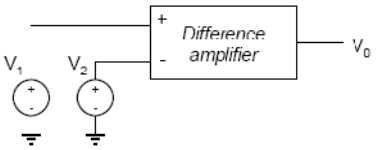
$$I_L = \frac{V_{in}}{R}$$

SISTEM PENGUKURAN

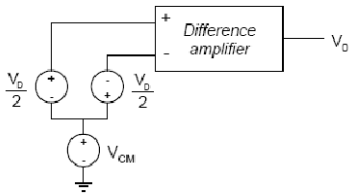
Amplifier : Instrumentation Amplifier

- Differential Amplifier





- Tegangan COMMON MODE & DIFFERENCE MODE



$$V_{CM} = \frac{V_2 + V_1}{2}$$

$$V_D = V_2 - V_1$$

SISTEM PENGUKURAN

Amplifier : Instrumentation Amplifier

- Jika R input 1 & 2 tidak identik, maka gain pada kedua input tidak sama

$$V_0 = G(V_2 - V_1) \overset{R_k' \neq R_k}{=} G_2 V_2 - G_1 V_1 = G_2\left(-\frac{V_D}{2} + V_{CM}\right) - G_1\left(\frac{V_D}{2} + V_{CM}\right) =$$

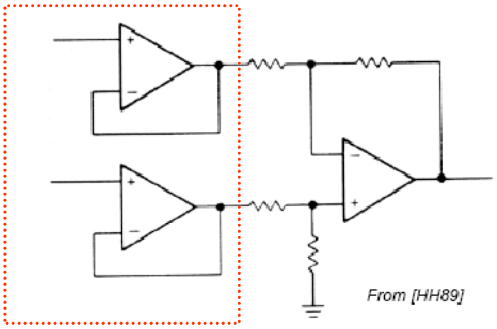
$$= -V_D\left(\frac{G_2 + G_1}{2}\right) + V_{CM}(G_2 - G_1) = -V_D G_D + V_{Cm} G_{CM}$$

- Didefinisikan Common Mode Rejection Ratio (CMRR)
  - **CMRR** merupakan fungsi frekuensi dan besarannya menurun dengan kenaikkan frekuensi

$$CMRR = 20\log_{10}\left(\frac{G_D}{G_{CM}}\right) = 20\log_{10}\left(\frac{G_2 + G_1}{2(G_2 - G_1)}\right)$$

Amplifier : Instrumentation Amplifier

- Terminologi INSTRUMENTATION AMPLIFIER digunakan untuk Differential Amplifier dengan
  - High Gain
  - Single ended Output
  - High input impedance
    - Dapat dilakukan dengan *buffering*
  - High CMRR



From [HH89]

Filter

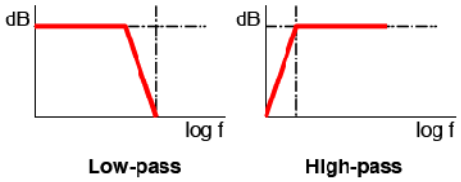
- Filter digunakan untuk membuang sinyal dengan frekuensi yang tidak diinginkan
- Klasifikasi filter berdasarkan implementasi
  - **Filter aktif** (termasuk rangkaian RC dan op-amp)
  - **Filter pasif**
    - Terdiri atas rangkain RLC
  - **Filter digital**

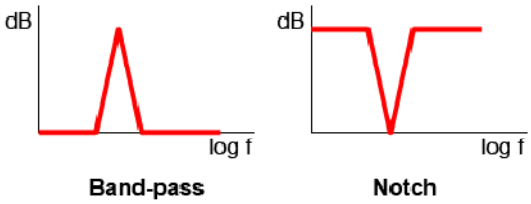
SISTEM PENGUKURAN

Filter

Klasifikasi Filter berdasarkan respon frekuensi

- Low pass filter
- High pass filter
- Bandpass filter
- Band Stop (notch)

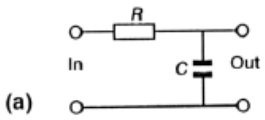


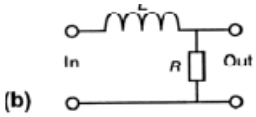


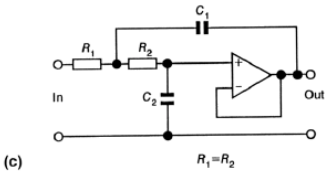
SISTEM PENGUKURAN

Filter

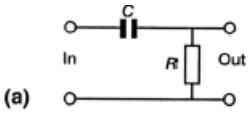
- Low pass filter

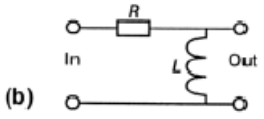


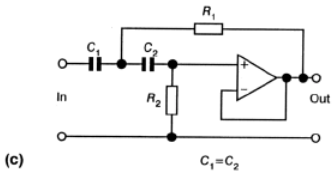




- High pass filter



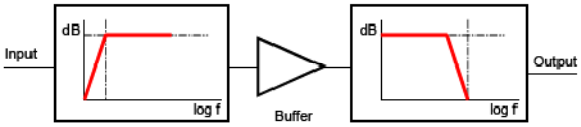




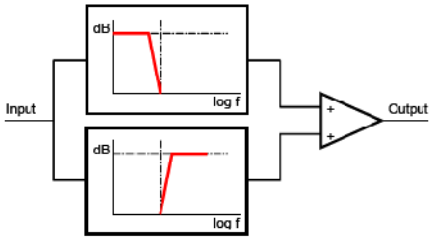
SISTEM PENGUKURAN

Filter

- Bandpass filer
  - Hubungan seri HPF & LPF
  - HPF harus memiliki *corner frequency* yang lebih rendah
  - Antar HPF dan LPF harus digunakan buffer



- Band stop filter (notch)
  - Hubungan paralel HPF dan LPF
  - HPF harus memiliki *corner frequency* yang lebih tinggi

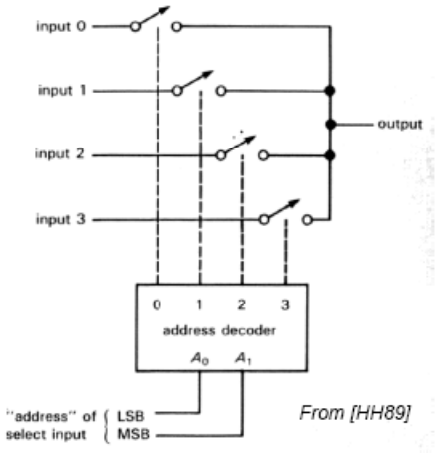


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SISTEM PENGUKURAN

PEMROSES SINYAL : Multiplexing

- Rangkaian untuk memilih salah satu input dengan sinyal kontrol digital



From [HH89]

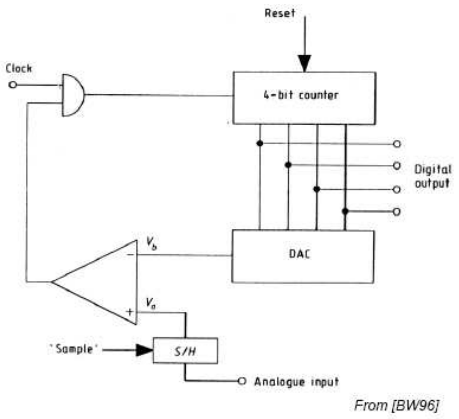
220

SISTEM PENGUKURAN

PEMROSES SINYAL : Analog – Digital Converter

Single Slope atau Ramp ADC

- Terdiri atas
  - Counter biner
  - DAC
  - Komparator analog
- Cara kerja
  - Reset counter
  - Input analog dicacah
  - Jika $V_A > V_B$ counter naik
  - Jika $V_A = V_B$ counter berhenti dan kode biner merupakan output
- Karakteristik
  - Relatif lambat karena waktu konversi dapat mencapai 2^N, dimana N adalah resolusi ADC



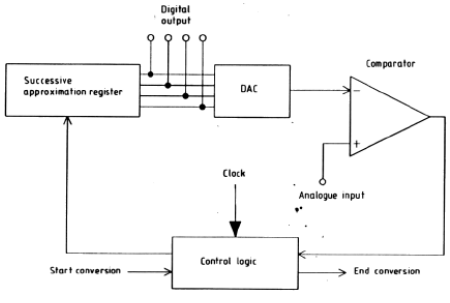
From [BW96]

SISTEM PENGUKURAN

PEMROSES SINYAL : Analog – Digital Converter

Successive approximation ADC

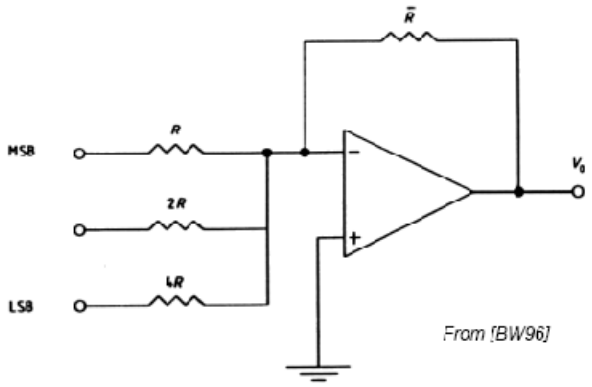
- Terdiri atas
  - DAC
  - Komparator analog
  - Modul logic kontrol
  - Successive Approx Register
- Cara kerja
  - Kondisi awal : semua bit sama dengan NOL kemudian dimulai dengan MSB sama dengan 1 (10000…..0)
    - Jika analog input lebih besar, maka MSB = 1 atau MSB = 0
    - Regiister melakukan operasi yang sama dari MSB ke LSB



SISTEM PENGUKURAN

PEMROSES SINYAL : Digital – Analog Converter

- Binary weighted ladder
  - Setiap input diberi bobot oleh masing-masing resistor pada rangkaian op-amp



From [BW96]