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ELECTRONIC SYSTEMS

2021-22 academic year

prof. Franco ZAPPA

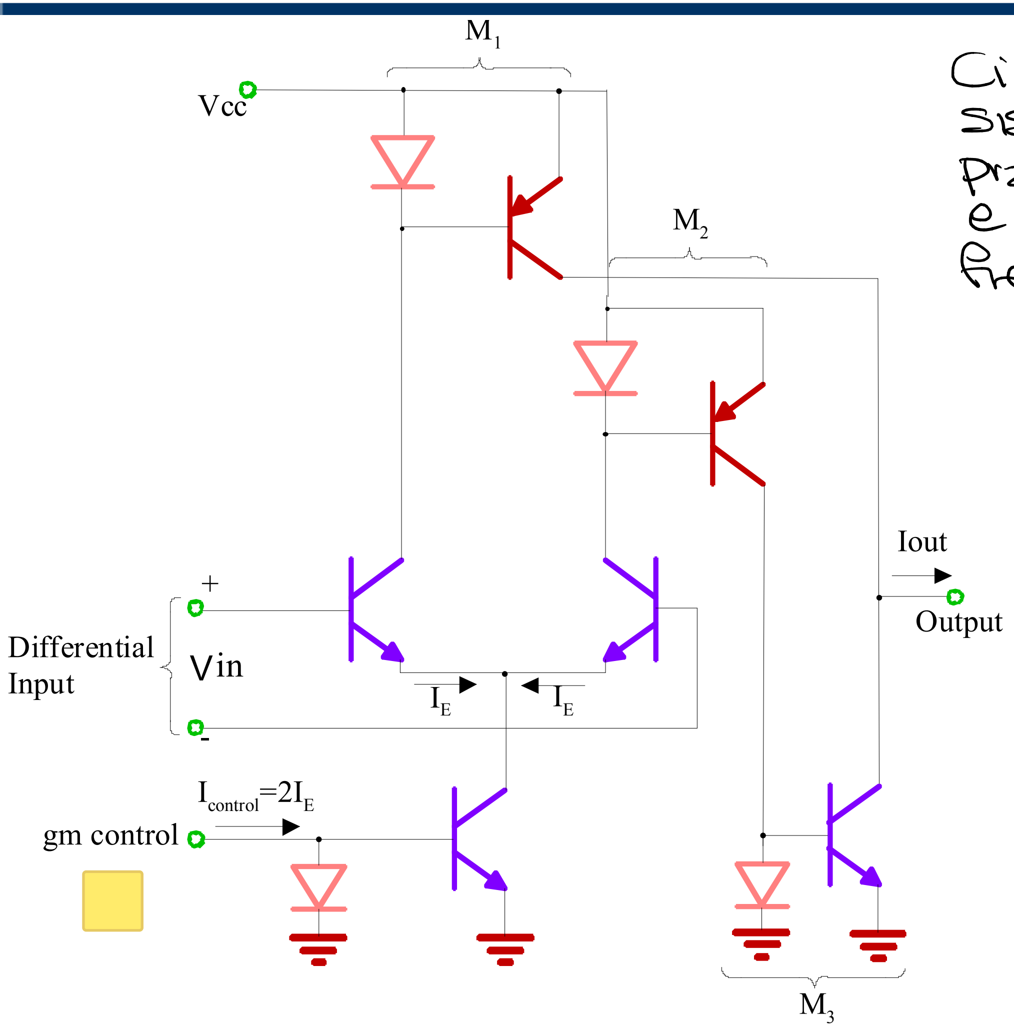
Summary 08 – OTA and ISO amplifiers

- Operational Transconductance Amplifier (OTA)

- Isolation amplifier (ISO)

- ~~Norton amplifier~~

OTA, Operational Transconductance Amplifier



Ci sono capacità parassite nel sistema ma visto che le resistenze a praticamente tutti i nodi sono a 1/gm e quindi i poli sono tutti ad altissima frequenza.

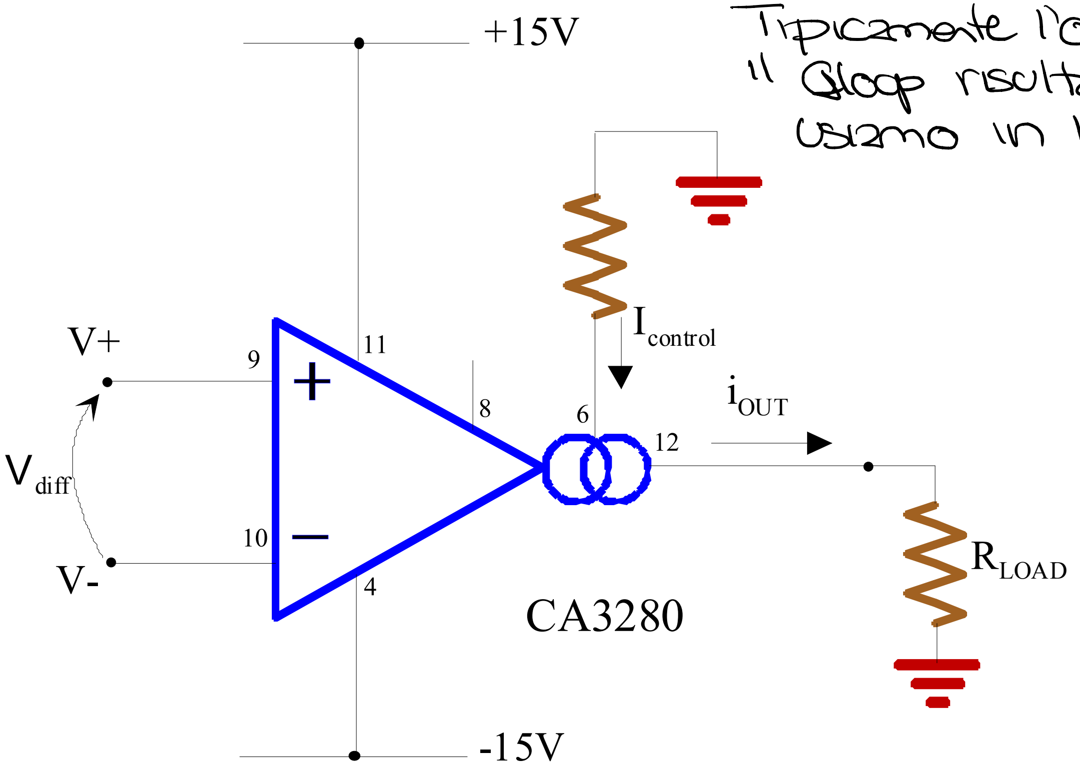
$$g_m = \frac{dI_{OUT}}{dV_{diff}} = \frac{dI_{OUT}}{d\left(V_+ - V_-\right)} = \frac{I_E}{kT/q}$$

both inputs be high impedance (like VOA)

output be current (like Norton)

transconductance gain (I_{out}/V_{diff}) adjustable through a pin!

OTA: external connections



Tipicamente l'ota non si usa in negative feedback perché il Gloop risulta troppo piccolo. Per questo noi non lo usiamo in loop.

$$i_{out} = G_m(I_{control})\cdot v_{diff} = \frac{I_{control}}{kT/q}\cdot v_{diff} = \frac{I_{control}}{25mV}\cdot v_{diff}$$

Advantages:

all low-impedance nodes

wide bandwidth

$f_{pole} = 1/2\pi C_{LOAD} R_{LOAD}$

Disadvantages:

no infinite gain

no “VIRTUAL GROUND”

it is used open-loop

OTA: standard input stage

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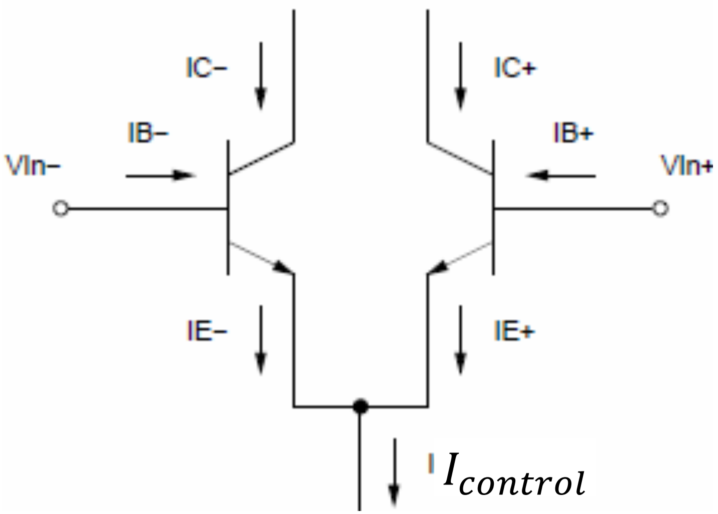
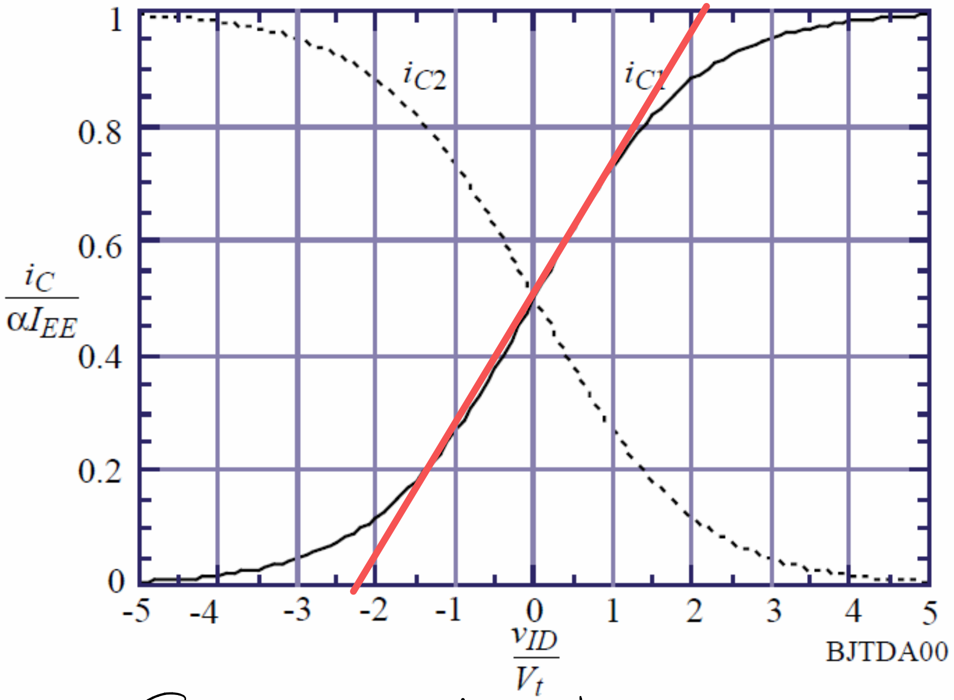
$$I_{out} = I_{C+} - I_{C-} = I_{control} \cdot tanh\frac{V_{diff}}{2 \cdot kT/q}$$

L'OTA è lineare solo per piccole tensioni differenziali (ordine delle centinaia mV)



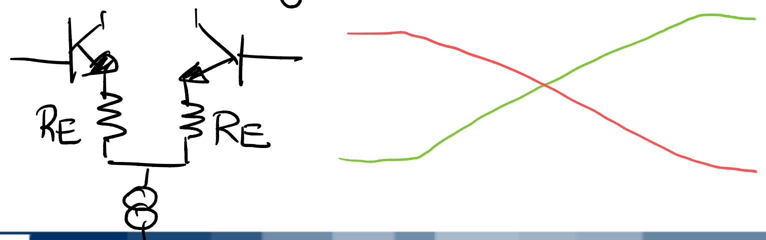
$$\frac{I_C}{I_{control}}$$



The transconductance is anything but constant !!!

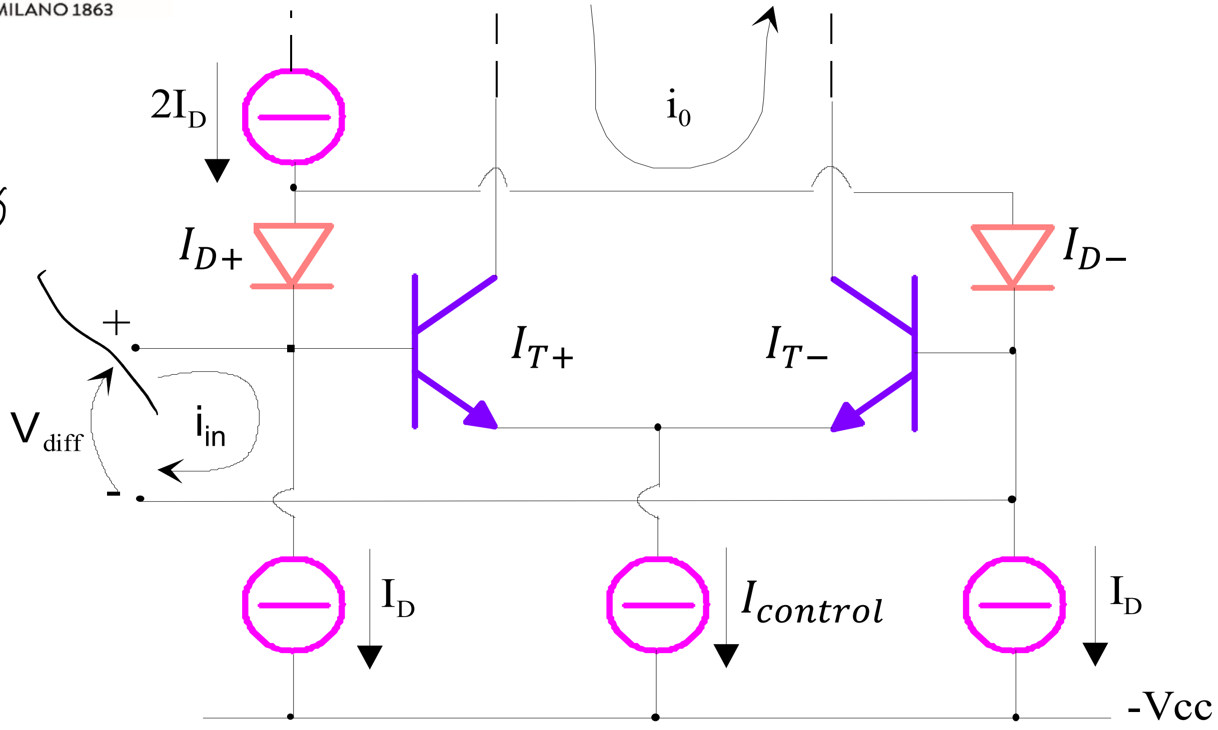
$$g_m = \frac{I_{control}}{2 \cdot kT/q} \cdot sech^2\frac{V_{diff}}{2 \cdot kT/q}$$

Se voglio lo stage + lineare uso la topologia



OTA: improved dynamics and linearity

$i_{in} = \emptyset$



$$I_{in} = I_D - I_{D+} = -(I_D - I_{D-})$$

Now there is an input current !!!

$$I_{in} = I_{D-} - I_{D+} = I_+ - I_-$$

But the out/in relationship is linear!!!

$$I_{out} = I_{C+} - I_{C-} = \frac{I_{control}}{I_d} \cdot I_{in}$$

where $|I_{in}|<I_d$

Ha usato una slide che non ho (Non ho seguito)

Translinear principle: $I_{D+} \cdot I_{T+} = I_{D-} \cdot I_{T-}$

Node currents: $I_{D+} = I_D - I_{in}$ $\quad I_{D-} = I_D + I_{in}$

Output signal current: $I_{out} = I_{T+} - I_{control} = I_{control} - I_{T-}$

Example of OTA application: voltage-controlled low-pass filter

È IN FEEDBACK Ma parecchie avevamo detto che non l'avremmo usato perché il Gloop è piccolo. Tuttavia qua lo usiamo perché aumentiamo Gloop.

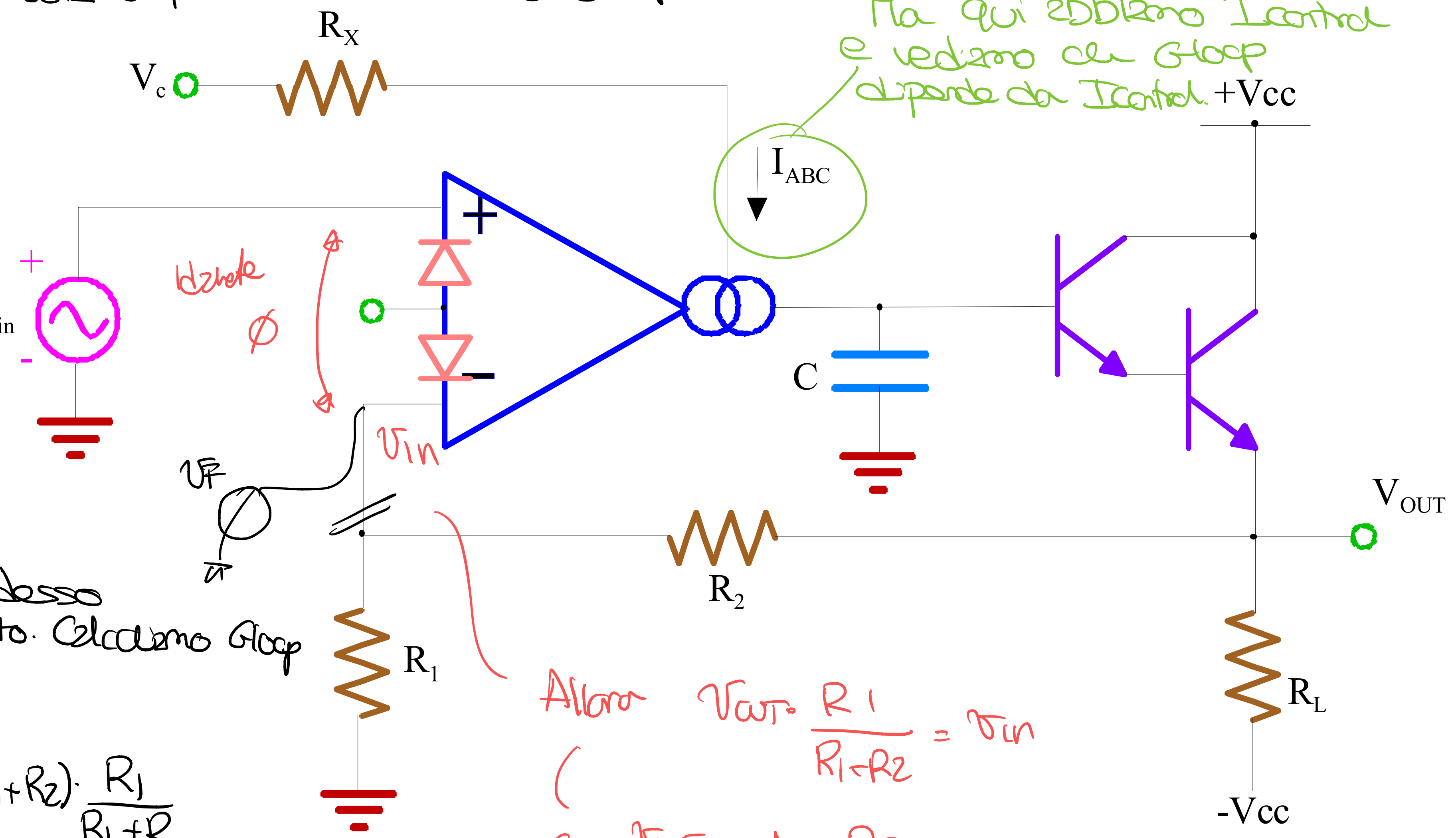
i.e. $f_{pole}(V_c)$

L'OTA da in uscita una corrente e io voglio in uscita una corrente

Allora uso un transistor Darlington

i_{in} i_{out}

$\frac{i_{out}}{i_{in}} = (\beta+1)^2$ ← così adesso posso dire che Gloop è alto. Calcoliamo Gloop



Ma qui abbiamo Icontrol e vediamo che Gloop dipende da Icontrol.

Idealmente $\emptyset$

v_{in}

v_F

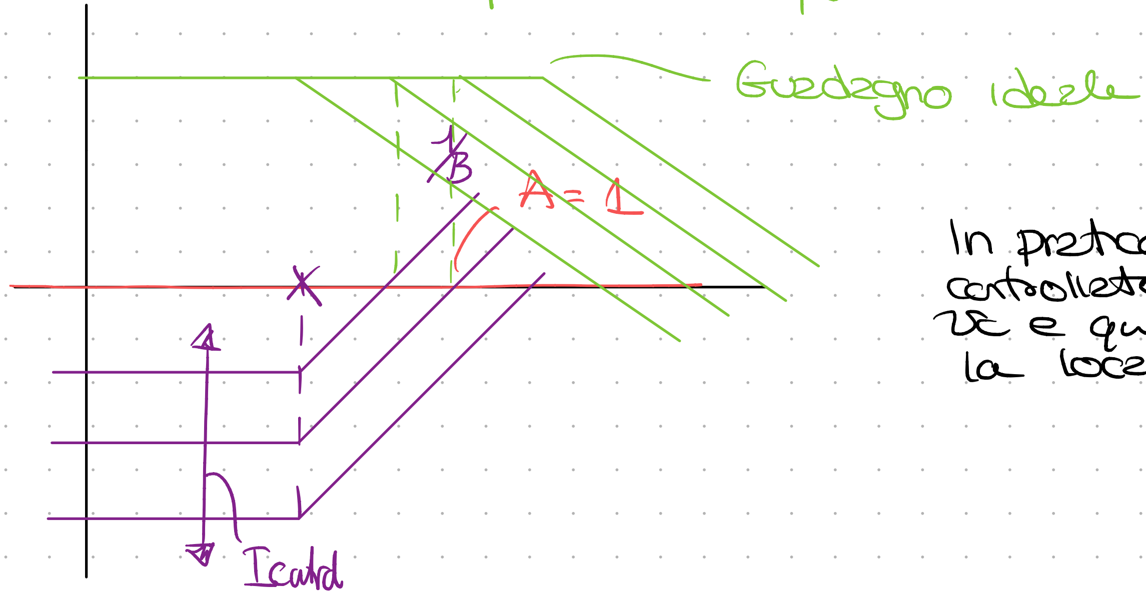
Allora $V_{out} \cdot \frac{R_1}{R_1+R_2} = v_{in}$

$G = \frac{v_{out}}{v_{in}} = 1 + \frac{R_2}{R_1}$

$$G_{loop} = v_F \cdot g_m \cdot (\beta+1)^2 \cdot R_L//(R_1+R_2) \cdot \frac{R_1}{R_1+R}$$

$$= \frac{I_{control}}{25mV} \cdot 10000 \cdot 1K\Omega \cdot \frac{10K}{11K} >>> 1$$

Considero tutto il circuito come B tranne il pezzo di filo che va da R1 21 -



In pratica ho un passa basso controllato perché tramite la tensione Vc e quindi Icontrol posso variare la locazione del polo

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Data-sheet CA3280:

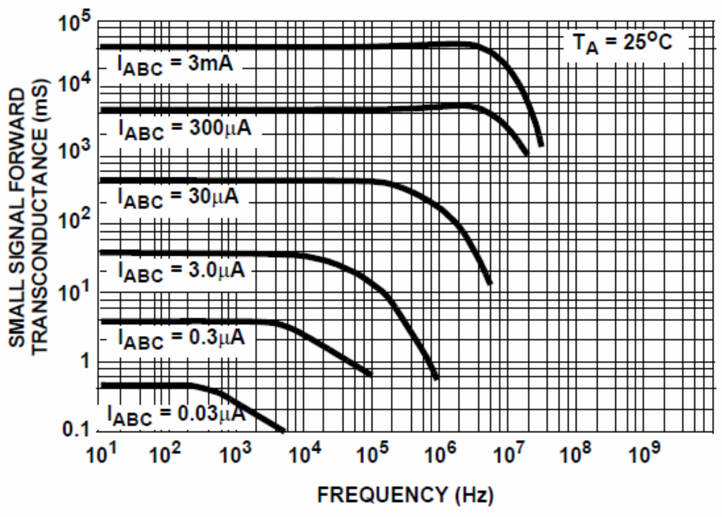


FIGURE 11. AMPLIFIER GAIN vs FREQUENCY

intersil

CA3280, CA3280A

Data Sheet **May 2002** **FN1174.6**

Dual, 9MHz, Operational Transconductance Amplifier (OTA)

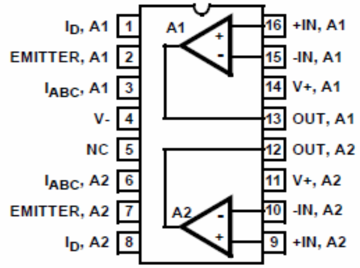
The CA3280 and CA3280A types consist of two variable operational amplifiers that are designed to substantially reduce the initial input offset voltage and the offset voltage variation with respect to changes in programming current. This design results in reduced "AGC thump," an objectionable characteristic of many AGC systems. Interdigitation, or crosscoupling, of critical portions of the circuit reduces the amplifier dependence upon thermal and processing variables.

The CA3280 has all the generic characteristics of an operational voltage amplifier except that the forward transfer characteristics is best described by transconductance rather than voltage gain, and the output is current, not voltage. The magnitude of the output current is equal to the product of transconductance and the input voltage. This type of operational transconductance amplifier was first introduced in 1969, and it has since gained wide acceptance as a gateable, gain controlled building block for instrumentation and audio applications, such as linearization of transducer outputs, standardization of widely changing signals for data processing, multiplexing, instrumentation amplifiers operating from the nanopower range to high current and high speed comparators.

For additional application information on this device and on OTAs in general, please refer to Application Notes: AN6818, AN6668, and AN6077.

Pinout

CA3280 (PDIP)
TOP VIEW



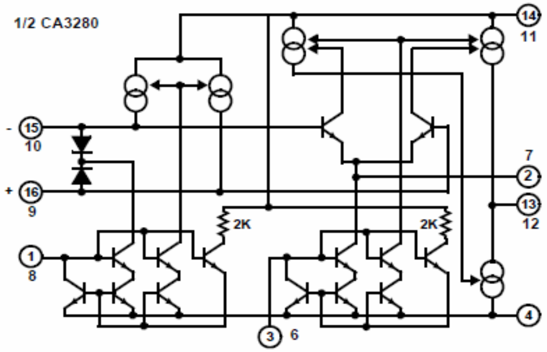
Features

- Low Initial Input Offset Voltage: 500μV (Max) (CA3280A)
- Low Offset Voltage Change vs I_{ABC}: <500μV (Typ) for All Types
- Low Offset Voltage Drift: 5μV/^{o}C (Max) (CA3280A)
- Excellent Matching of the Two Amplifiers for All Characteristics
- Internal Current-Driven Linearizing Diodes Reduce the External Input Current to an Offset Component
- Flexible Supply Voltage Range . . . . ±2V to ±15V

Applications

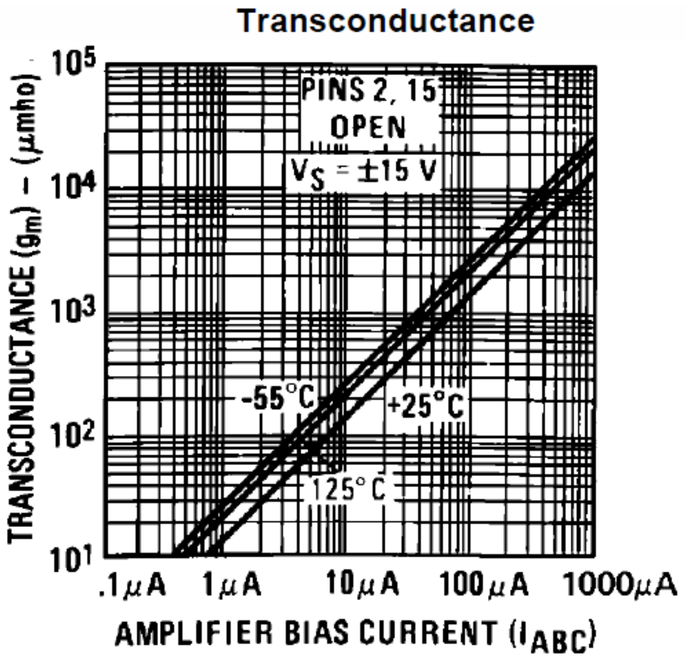
- Voltage Controlled Amplifiers
- Voltage Controlled Oscillators
- Multipliers
- Demodulators
- Sample and Hold
- Instrumentation Amplifiers
- Function Generators
- Triangle Wave-to-Sine Wave Converters
- Comparators
- Audio Preamplifier

Functional Diagram



OTA

Data-sheet LM13700:



TEXAS INSTRUMENTS

LM13700

www.ti.com

SNOSBW2E – NOVEMBER 1999 – REVISED MARCH 2013

LM13700 Dual Operational Transconductance Amplifiers with Linearizing Diodes and Buffers

Check for Samples: LM13700

FEATURES

- g_m Adjustable over 6 Decades
- Excellent g_m Linearity
- Excellent Matching between Amplifiers
- Linearizing Diodes
- High Impedance Buffers
- High Output Signal-to-Noise Ratio

APPLICATIONS

- Current-Controlled Amplifiers
- Current-Controlled Impedances
- Current-Controlled Filters
- Current-Controlled Oscillators
- Multiplexers
- Timers
- Sample-and-Hold circuits

DESCRIPTION

The LM13700 series consists of two current controlled transconductance amplifiers, each with differential inputs and a push-pull output. The two amplifiers share common supplies but otherwise operate independently. Linearizing diodes are provided at the inputs to reduce distortion and allow higher input levels. The result is a 10 dB signal-to-noise improvement referenced to 0.5 percent THD. High impedance buffers are provided which are especially designed to complement the dynamic range of the amplifiers. The output buffers of the LM13700 differ from those of the LM13600 in that their input bias currents (and hence their output DC levels) are independent of I_{ABC}. This may result in performance superior to that of the LM13600 in audio applications.

Connection Diagram

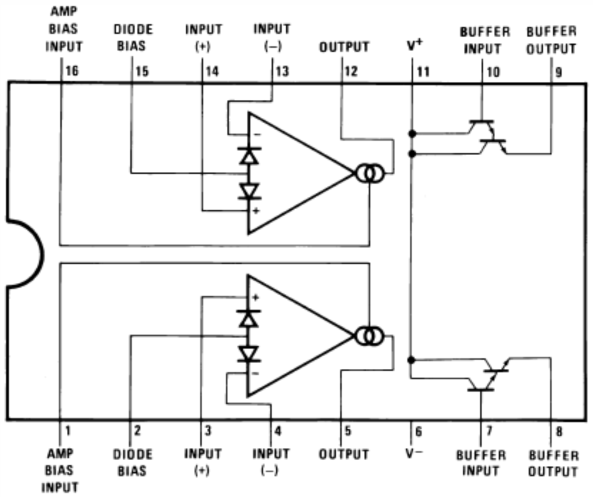


Figure 1. PDIP and SOIC Packages-Top View
See Package Number D0016A or NFG0016E

ISO, Isolation Amplifier

Non ci devono essere fili che colleghino l'output all'input.

Requirements:

isolated input and output stages

double power supply

galvanic isolation

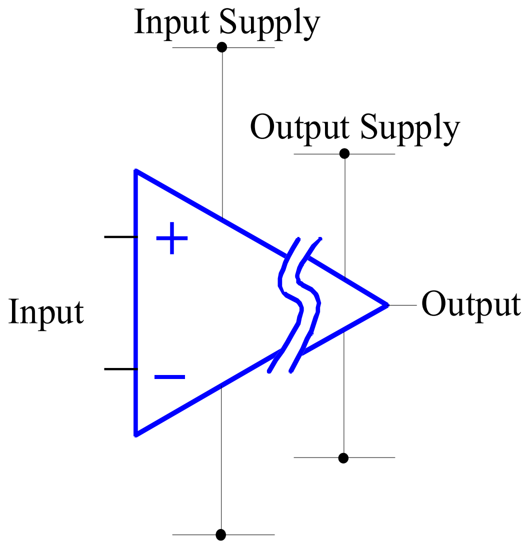
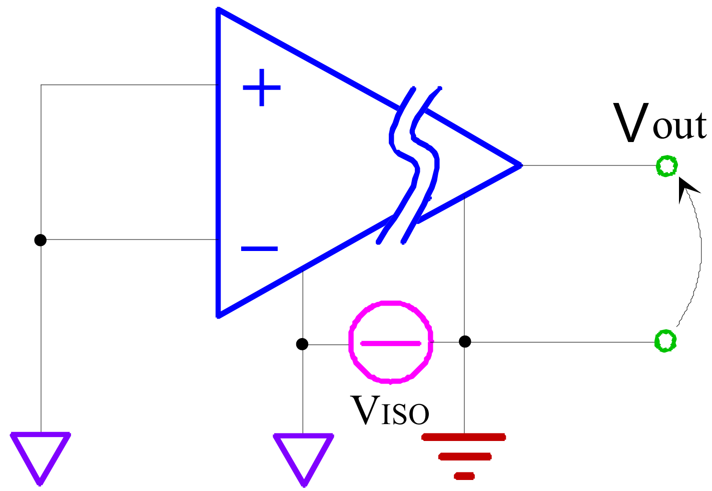


Figure of Merit: **Isolation Mode Rejection Ratio**

Idealmente vorremmo che per qualunque Viso la Vout è 0V



$$\text{IMRR} = 20\log\frac{V_{ISO}}{V_{OUT}/G}$$

error referred to the input stage

Nella realtà Viso genererà una Vout perciò possiamo ricavare un fattore di merito

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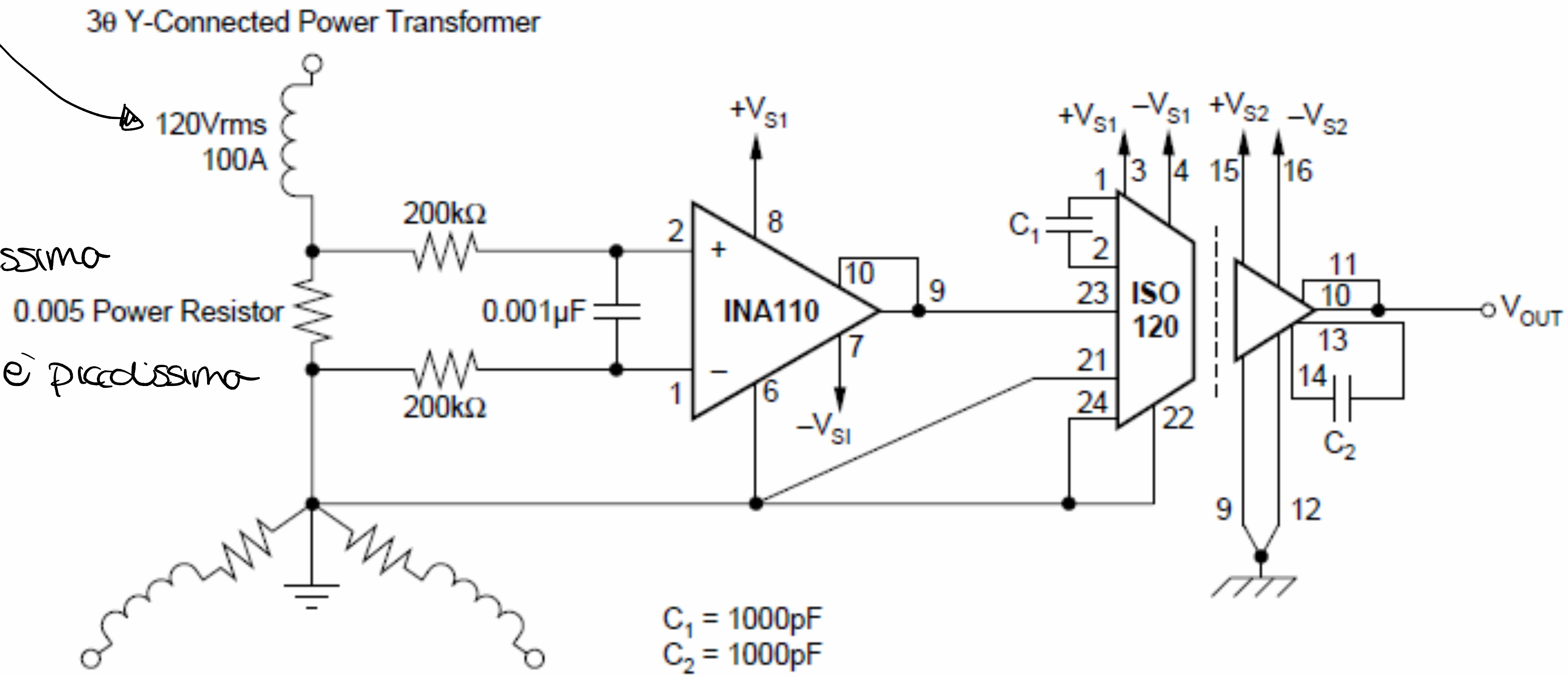
ISO, example of application

Isolated powerline monitor

è un motore trifase
montato a stella

Ai capi di questa
resistenza ho bassissima
tensione xè
benchè ci siano
altissime correnti R è piccolissima

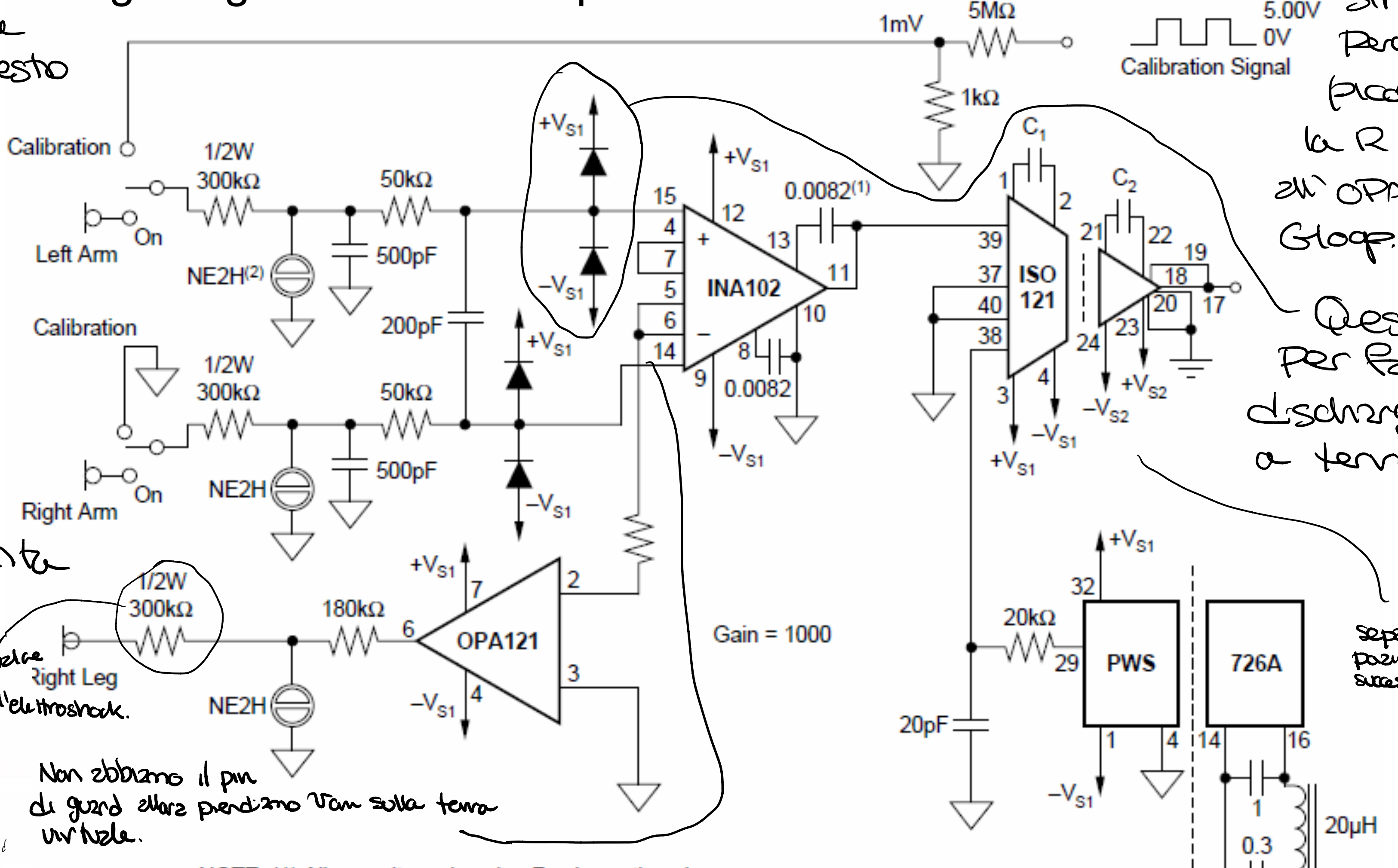


C_1 = 1000pF
C_2 = 1000pF
Differential input accurately senses power resistor voltage.
Two resistors protect INA110 from open power resistor.
High frequency spike reject filter has f_{CO} = 400Hz.

ISO, example of application

Right-leg driven ECG amplifier

Ma prendiamo il segnale alle 2 braccia ma questo segnale differenziale potrebbe avere un common mode che mi fa saturare l'INA allora potrei prendere il pin di guard e usare un opamp e attaccarlo al piede così quell'OPAMP fornisce la tensione di common mode invertita così la elimino



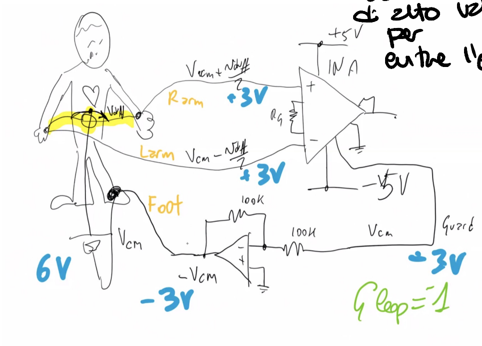
resistenza di alto valore per evitare l'elettroshock.

Non abbiamo il pin di guard allora prendiamo Vcm sulla terra virtuale.

Ma quello detto a sinistra non funziona perché Gloop è troppo piccolo, allora tolgo la R di retroazione all'OPAMP così aumento Gloop.

Questi diodi servono per fare sì che l'elettrostatic discharge venga scaricata a terra.

Iso per avere separazione galvanica tra paziente e elaborazione successiva del segnale

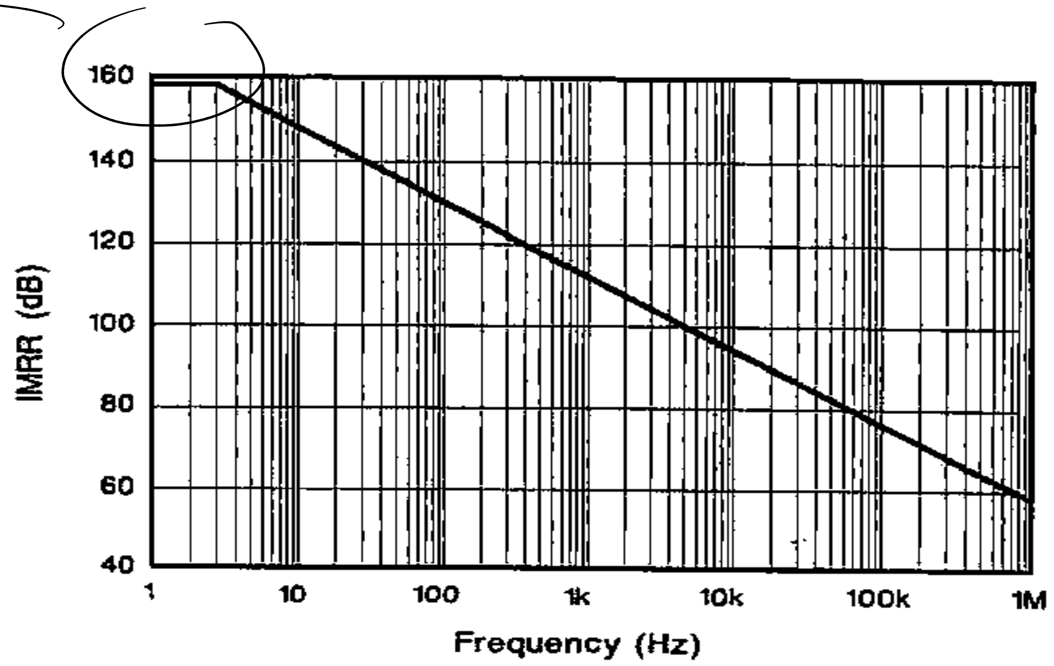


NOTE: (1) All capacitor values in µF unless otherwise noted. Diodes are IN4148. (2) NE2H: Neon bulb, max striking voltage $95V_{AC}$.

ISO: techniques

La reiezione dell' ISO è molto alta ma solo per frequenze molto basse.

IMRR frequency dependance



Transient Immunity: ISO122 TI < 1000V/ms

Isolation techniques:
- Optical
- Magnetic
- Capacitive

ISO: optical coupling

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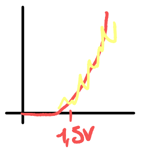
Esempi di come sono fatti questi ISO.

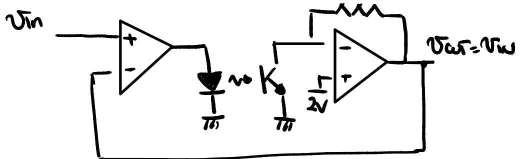
Questo perché ho diverse variazioni di



Capisco quindi che se comando il diodo in tensione questo non va bene.

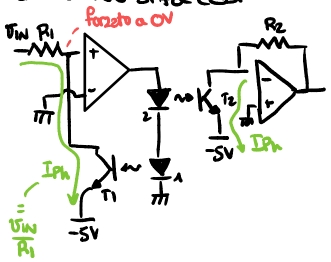
Dovrei comandare il Diodo in corrente. Ma anche in questo caso non va bene perché tra componenti diversi la curva di corrente non va bene

Però posso usare la non idealità dell'optoisolatore per eliminare la sua non idealità. Questo riesco a farlo usando 2 optoisolatori.



Bello ma ma stozza non posso mettere il cavo perché voglio isolamento

Quello vero si fa così



Iph scorre in T1 e quindi accendo il diodo 1 e quindi anche il 2° e quindi anche il T2 ha la stessa Iph

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

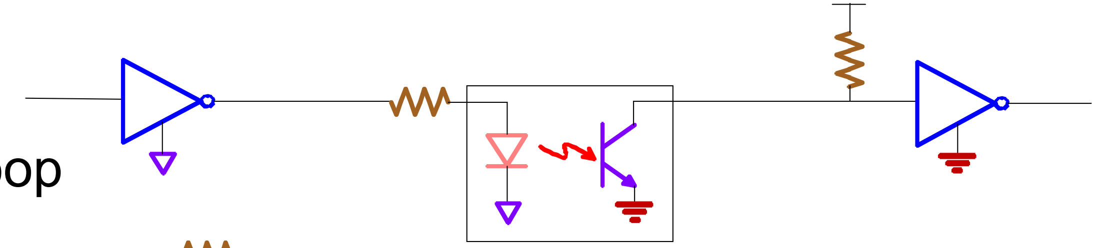
Advantages:

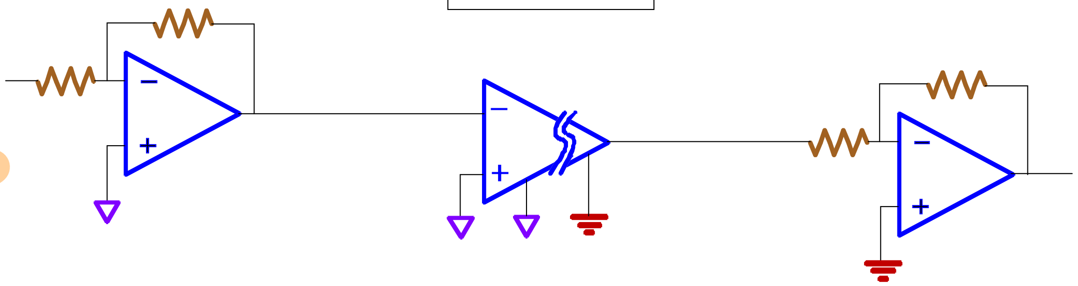
"light" breaks the "electrical" loop

high EMI

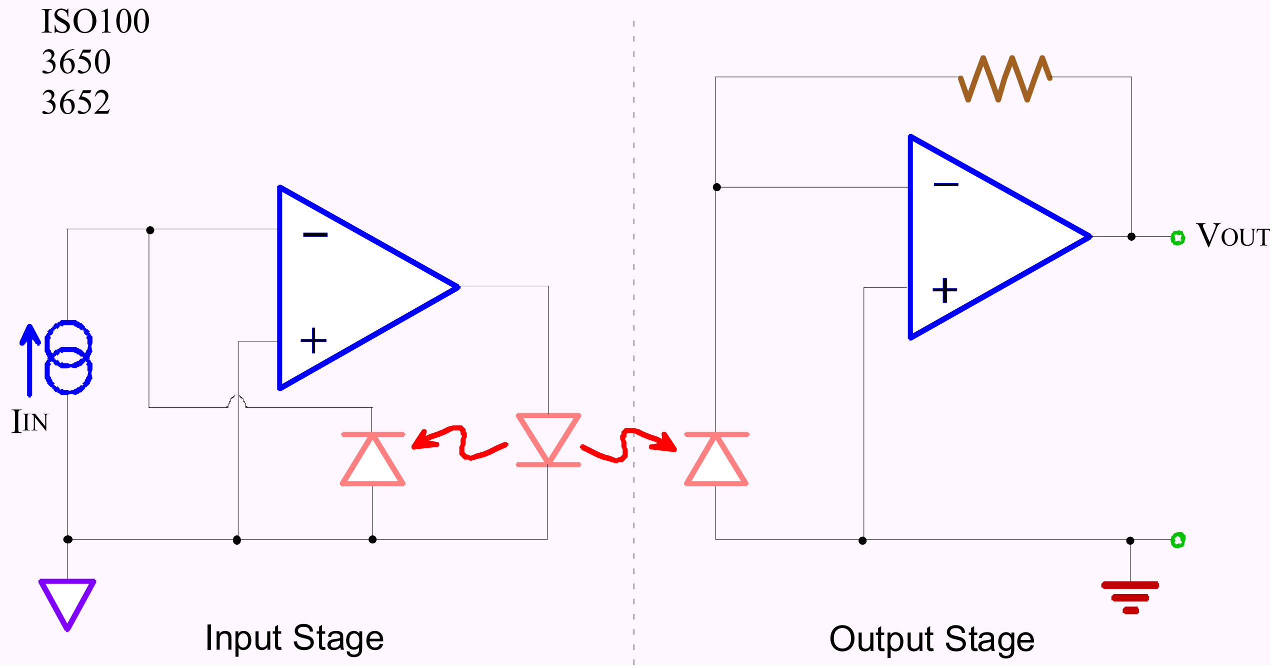
trivial for digital signals

problematic for analog signals



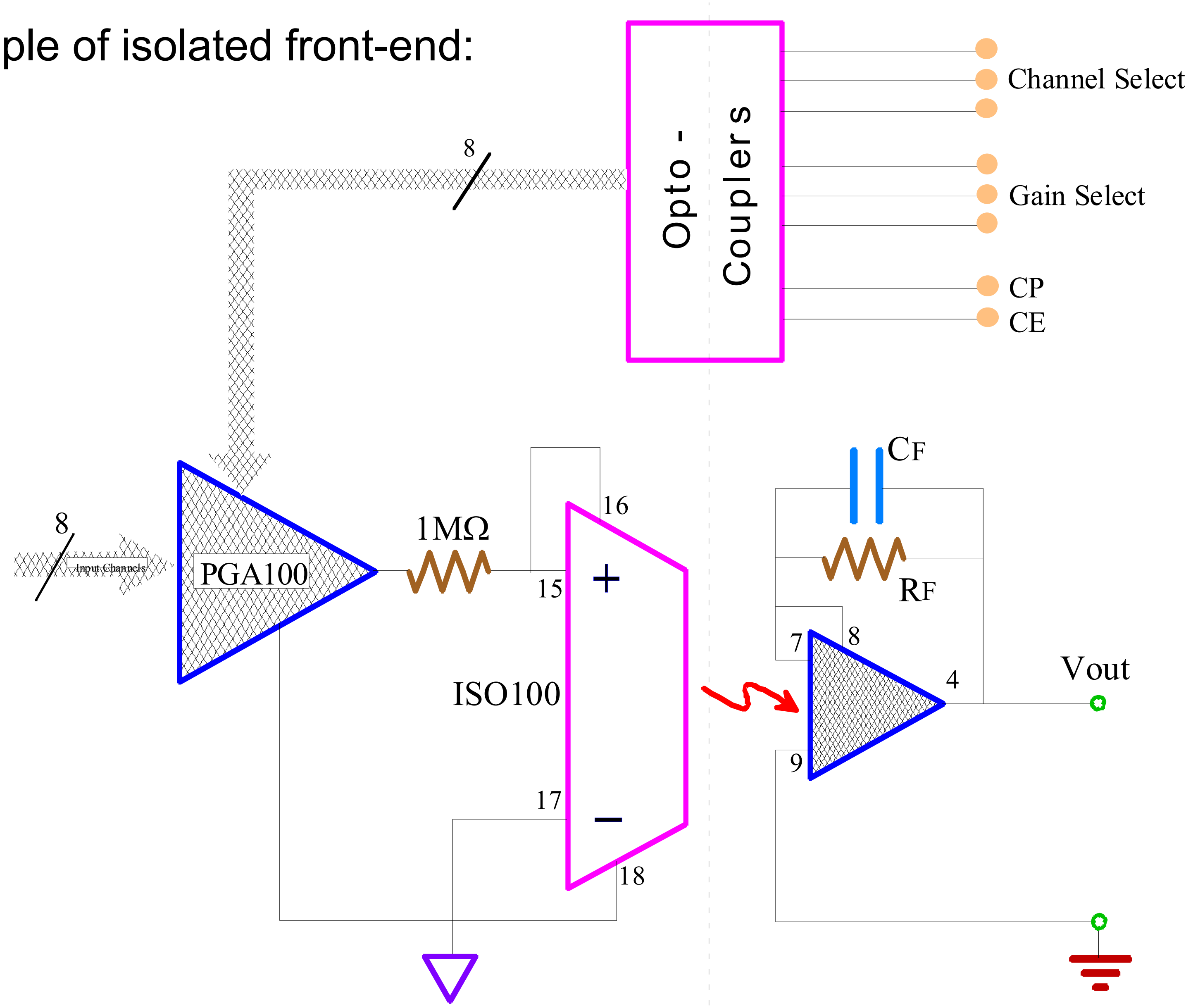


Example of optical coupling for analog signals:



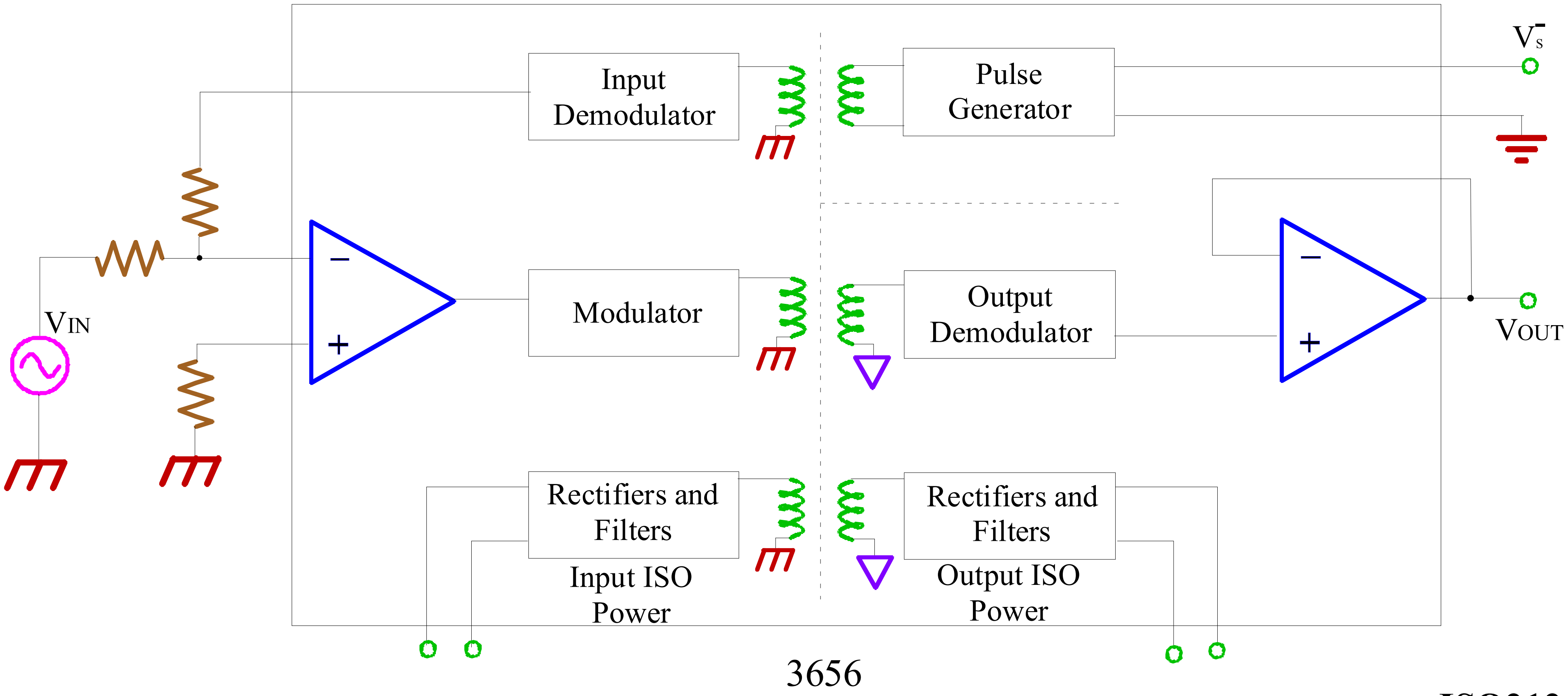
ISO: optical coupling

Example of isolated front-end:



ISO: magnetic coupling

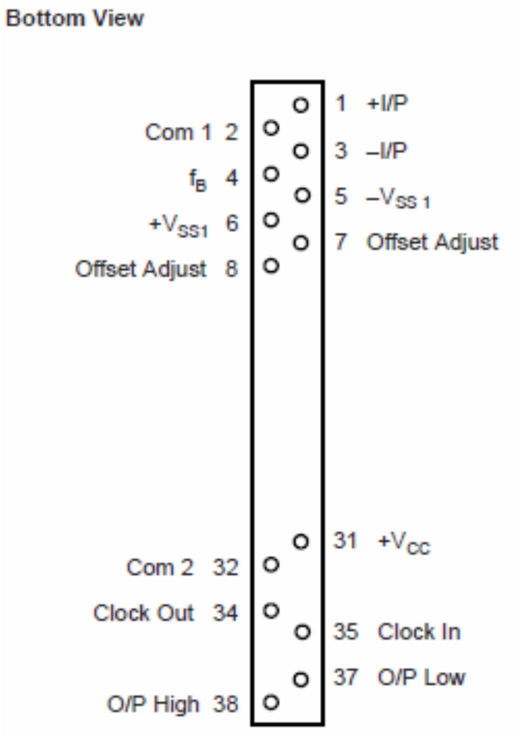
Hybrid and compact transformers with
modulation/demodulation techniques are needed



ISO212

ISO

Data-sheet:



BURR - BROWN®

ISO212P

Low Cost, Two-Port Isolated, 1500Vrms ISOLATION AMPLIFIER

FEATURES

- 12-BIT ACCURACY
- 2.5mA (typ) QUIESCENT CURRENT
- LOW PROFILE (LESS THAN 0.5" HIGH)
- SMALL FOOTPRINT
- EXTERNAL POWER CAPABILITY ($\pm$8V at 5mA)
- "MASTER/SLAVES" SYNCHRONIZATION CAPABILITY
- INPUT OFFSET ADJUSTMENT
- LOW POWER (53mW)
- SINGLE 10V TO 15V SUPPLY OPERATION

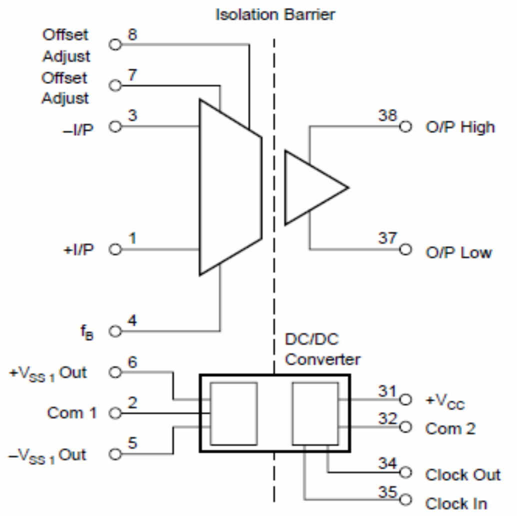
APPLICATIONS

- INDUSTRIAL PROCESS CONTROL: Transducer Channel Isolator for Thermocouples, RTDs, Pressure Bridges, Flow Meters
- 4mA TO 20mA LOOP ISOLATION
- MOTOR AND SCR CONTROL
- GROUND LOOP ELIMINATION
- ANALYTICAL MEASUREMENTS
- POWER PLANT MONITORING
- DATA ACQUISITION/TEST EQUIPMENT ISOLATION
- MULTIPLEXED SYSTEMS WITH CHANNEL TO CHANNEL ISOLATION

DESCRIPTION

The ISO212P signal isolation amplifier is a member of a series of low-cost isolation products from Burr-Brown. The low-profile SIL plastic package allows PCB spacings of 0.5" to be achieved, and the small footprint results in efficient use of board space.

To provide isolation, the design uses high-efficiency, miniature toroidal transformers in both the signal and power paths. An uncommitted input amplifier and an isolated external bipolar supply ensure the majority of input interfacing or conditioning needs can be met. The ISO212P accepts an input voltage range of $\pm$5V for single 15V supply operation or $\pm$3.0V for single 10V supply operation.

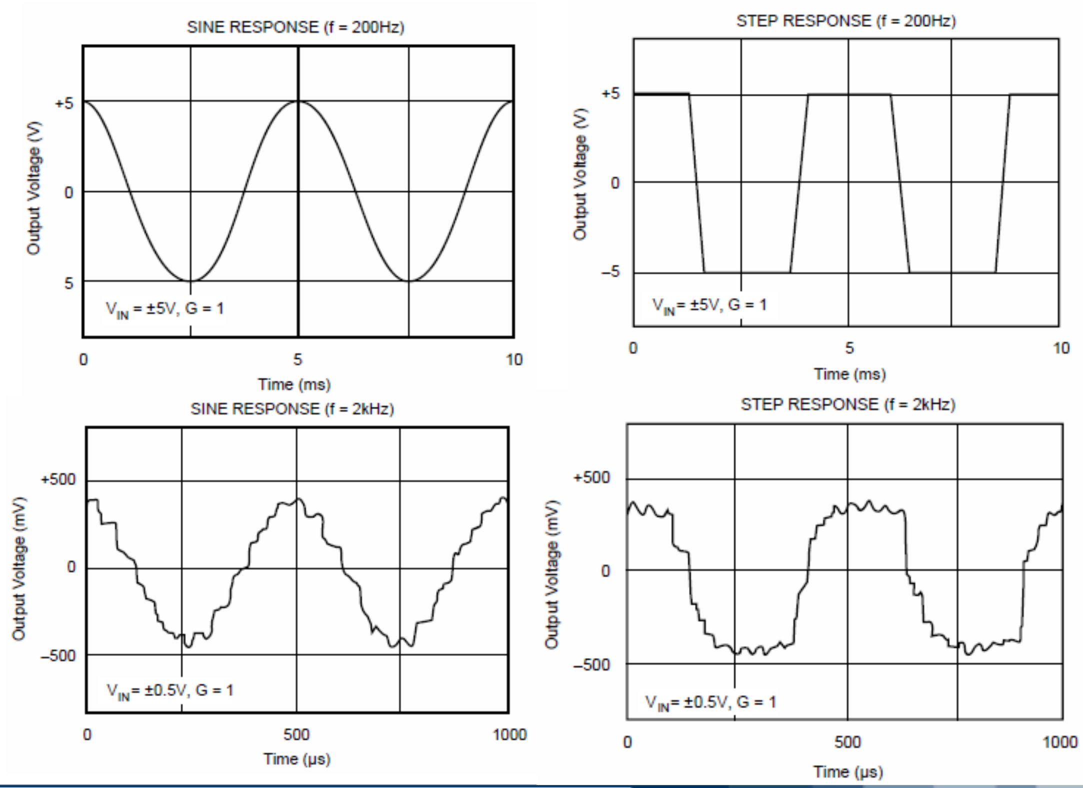


ISO: magnetic coupling

Disadvantages:

residual modulation ripple

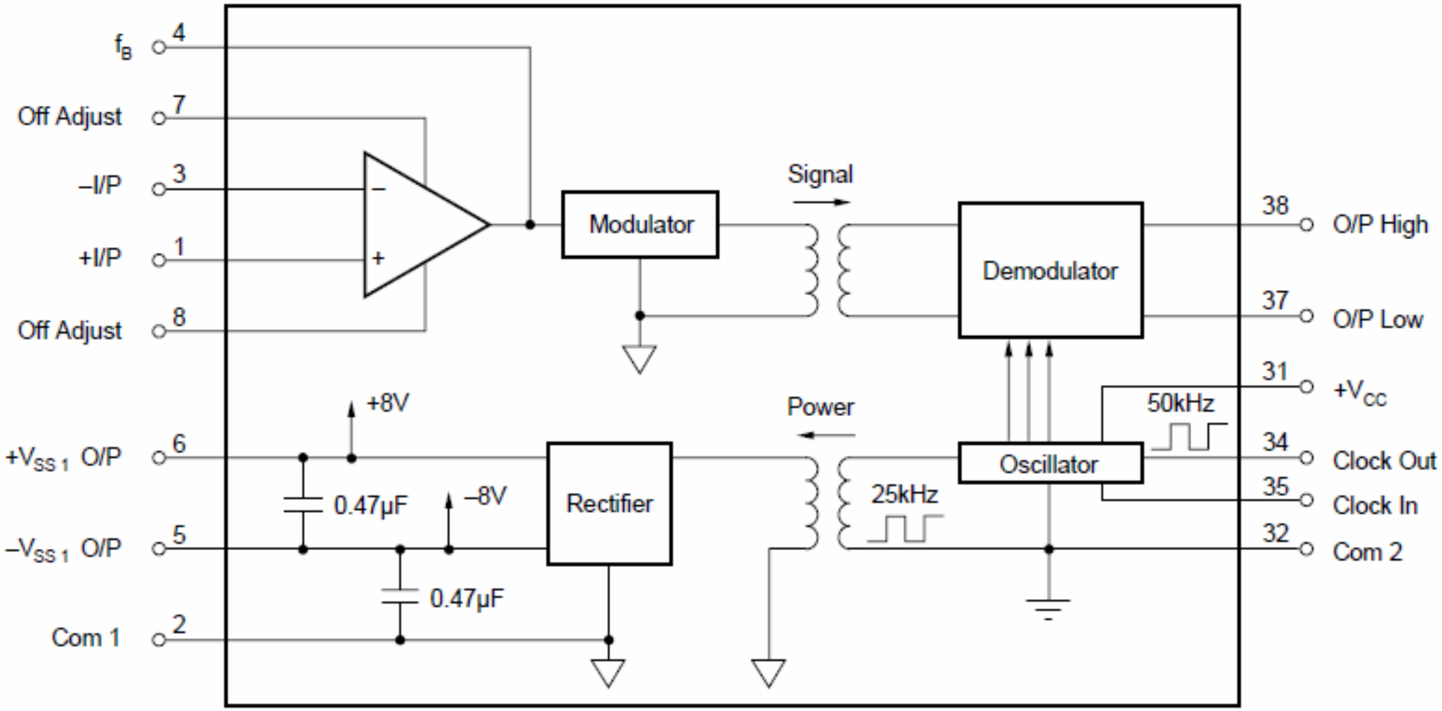
bulkness

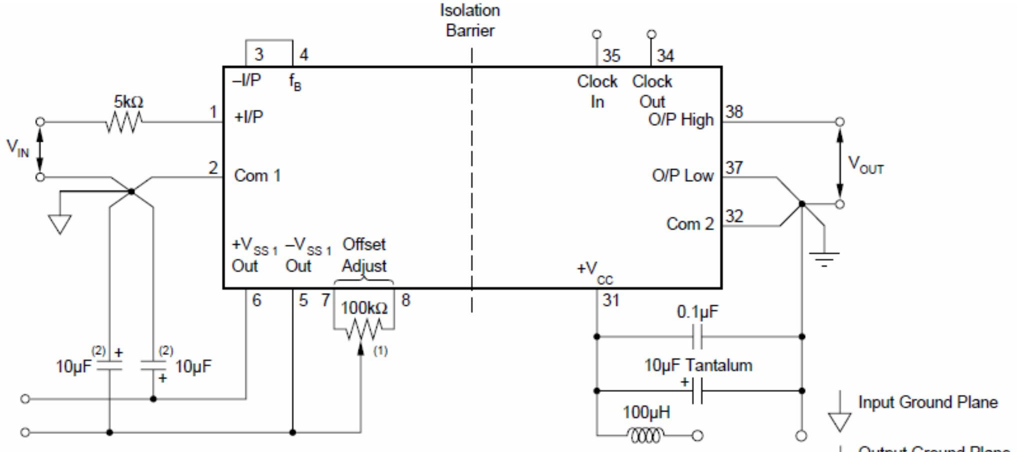


ISO: magnetic coupling

Advantages:

self-bias

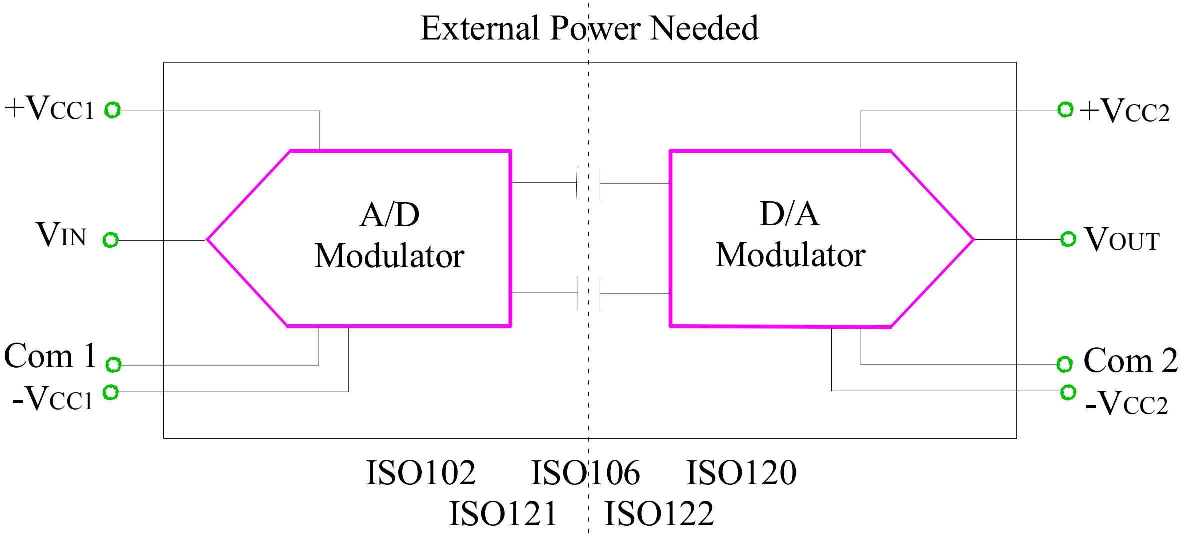




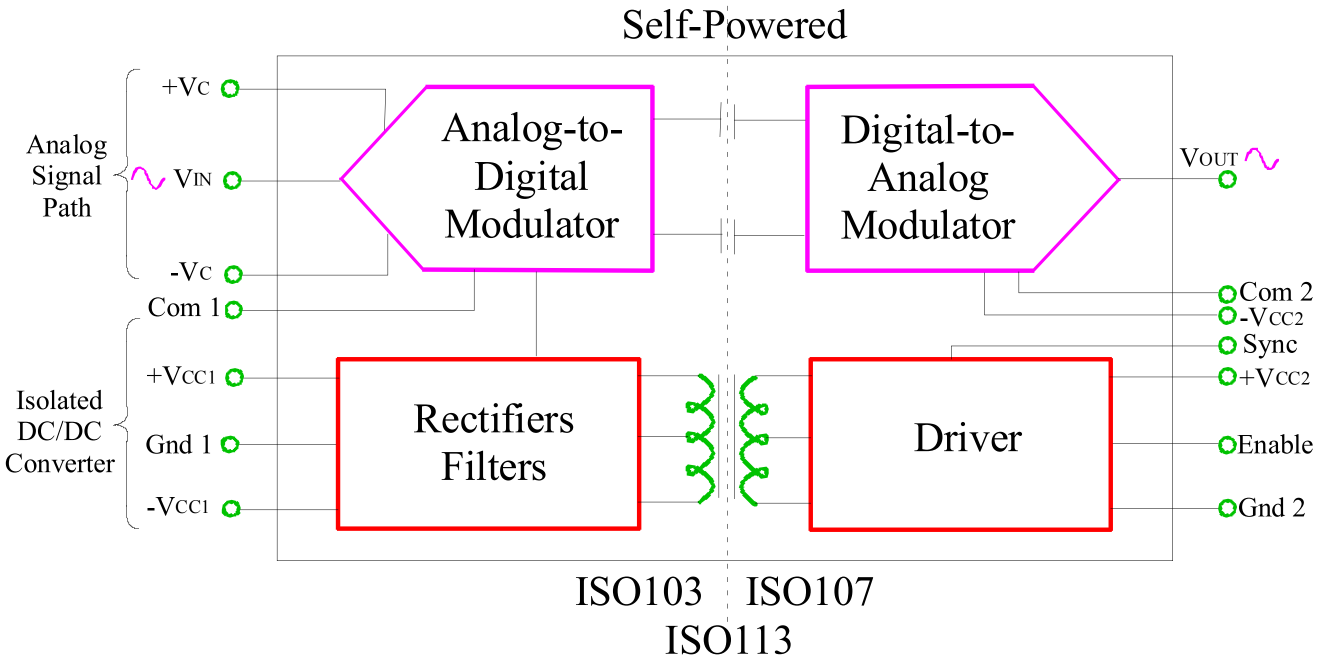
NOTES: (1) Optional voltage offset adjust components. (2) 10μF decoupling to be used with external loads connected.

ISO: capacitive coupling

Frequency or duty-cycle modulation/demodulation



On-chip generation of the power supply Of the other side



ISO: capacitive coupling

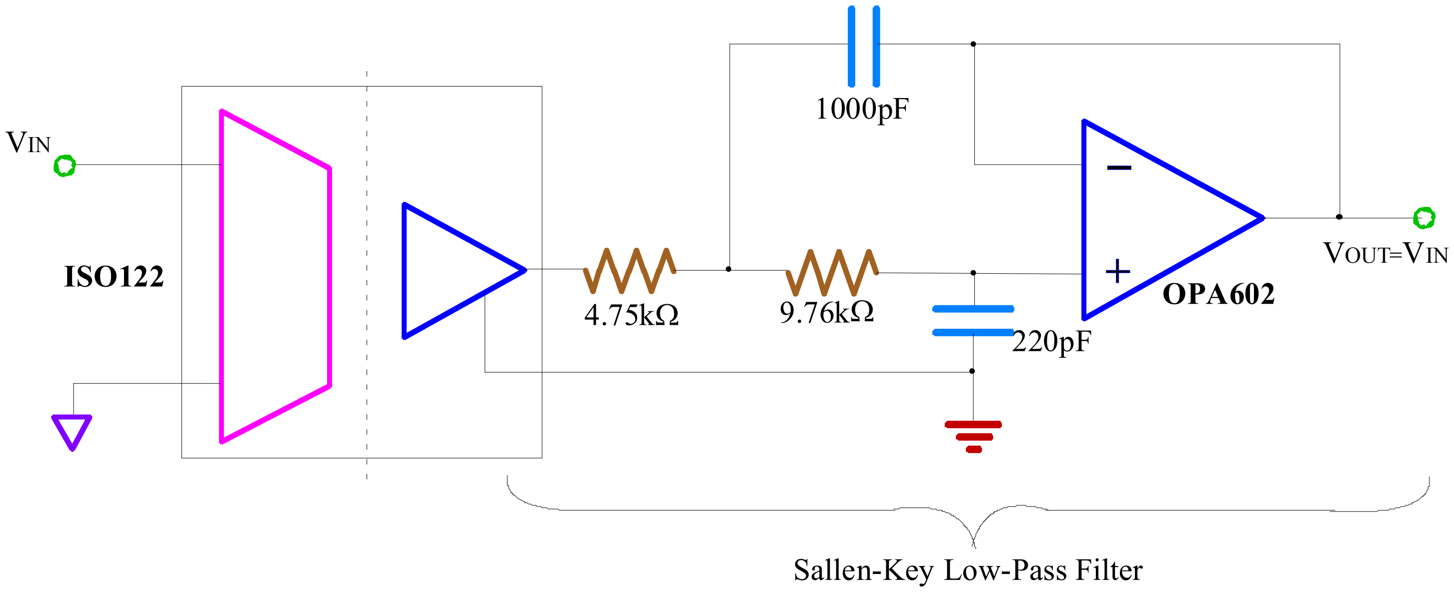
Disadvantages:

residual modulation ripple

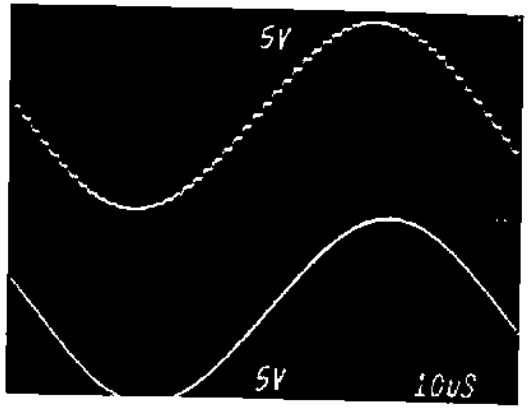
residual ADC/DAC quantization errors

bulkness

Need of output filtering:



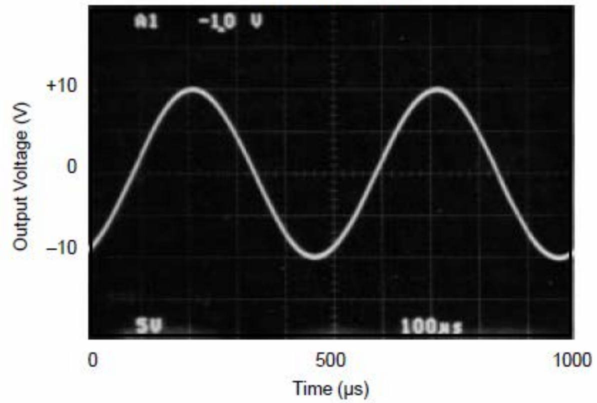
ISO122 Unfiltered vs Filtered Output



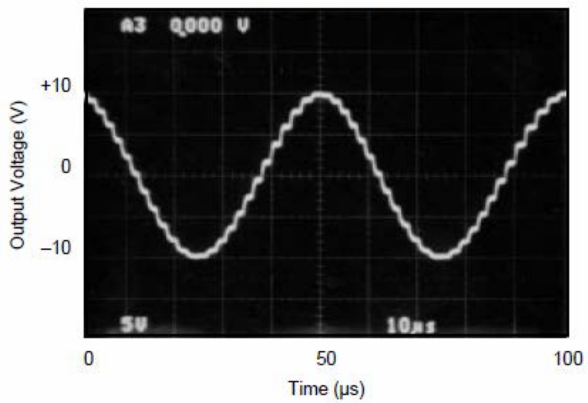
ISO

Data-sheet ISO120:

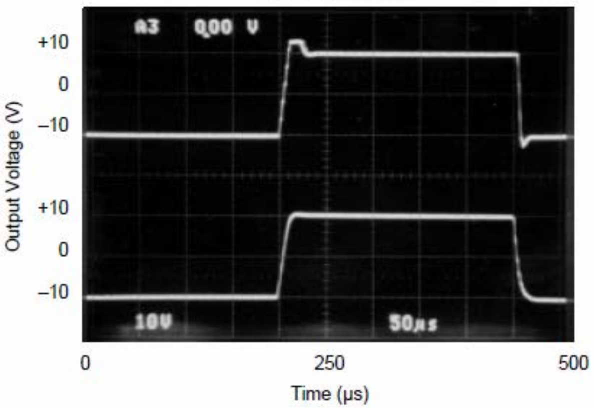
SINE RESPONSE
(f = 2kHz, C_2 = 0)



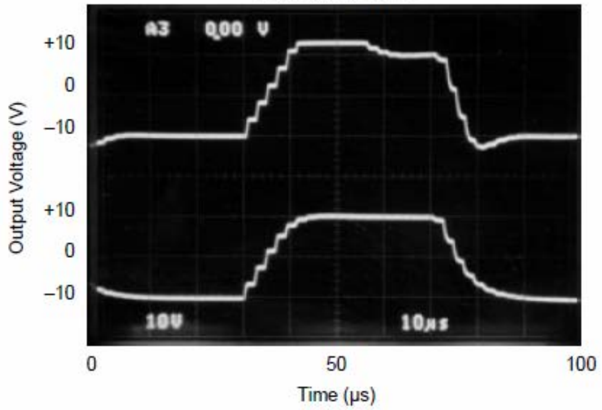
SINE RESPONSE
(f = 20kHz, C_2 = 0)



STEP RESPONSE



STEP RESPONSE



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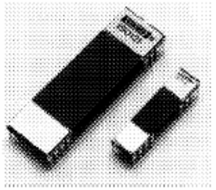


ISO120
ISO121

Precision Low Cost ISOLATION AMPLIFIER

FEATURES

- 100% TESTED FOR PARTIAL DISCHARGE
- ISO120: Rated 1500Vrms
- ISO121: Rated 3500Vrms
- HIGH IMR: 115dB at 60Hz
- USER CONTROL OF CARRIER FREQUENCY
- LOW NONLINEARITY: ±0.01% max
- BIPOLAR OPERATION: $V_O = \pm 10V$
- 0.3"-WIDE 24-PIN HERMETIC DIP, ISO120
- SYNCHRONIZATION CAPABILITY
- WIDE TEMP RANGE: –55°C to +125°C (ISO120)

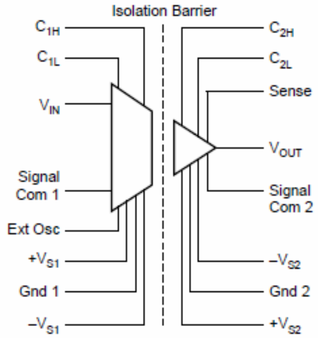
APPLICATIONS

- INDUSTRIAL PROCESS CONTROL: Transducer Isolator for Thermocouples, RTDs, Pressure Bridges, and Flow Meters, 4mA to 20mA Loop Isolation
- GROUND LOOP ELIMINATION
- MOTOR AND SCR CONTROL
- POWER MONITORING
- ANALYTICAL MEASUREMENTS
- BIOMEDICAL MEASUREMENTS
- DATA ACQUISITION
- TEST EQUIPMENT

DESCRIPTION

The ISO120 and ISO121 are precision isolation amplifiers incorporating a novel duty cycle modulation-demodulation technique. The signal is transmitted digitally across a 2pF differential capacitive barrier. With digital modulation the barrier characteristics do not affect signal integrity, which results in excellent reliability and good high frequency transient immunity across the barrier. Both the amplifier and barrier capacitors are housed in a hermetic DIP. The ISO120 and ISO121 differ only in package size and isolation voltage rating.

These amplifiers are easy to use. No external components are required for 60kHz bandwidth. With the addition of two external capacitors, precision specifications of 0.01% max nonlinearity and 150µV/°C max V_{OS} drift are guaranteed with 6kHz bandwidth. A power supply range of ±4.5V to ±18V and low quiescent current make these amplifiers ideal for a wide range of applications.



Conclusions

- Different OpAmps for different applications
- Need to properly understand application requirements and OpAmp specs

Now it’s time to go digital

Next lesson: **9 – Sampling**