

## Relazione

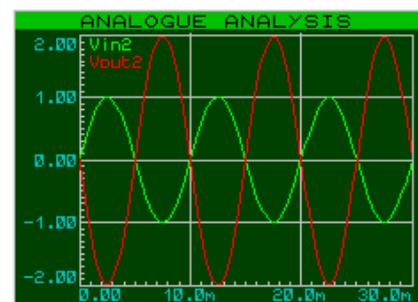
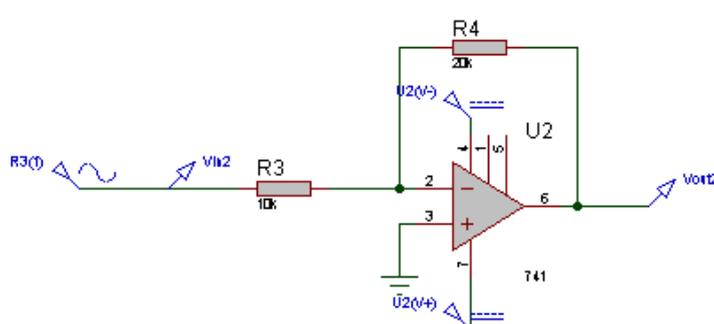
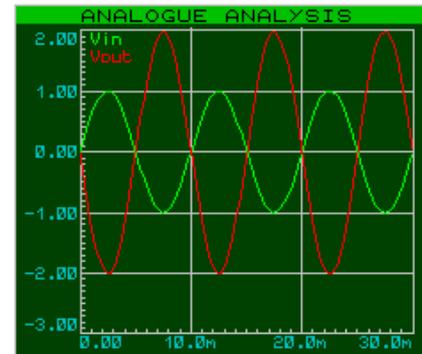
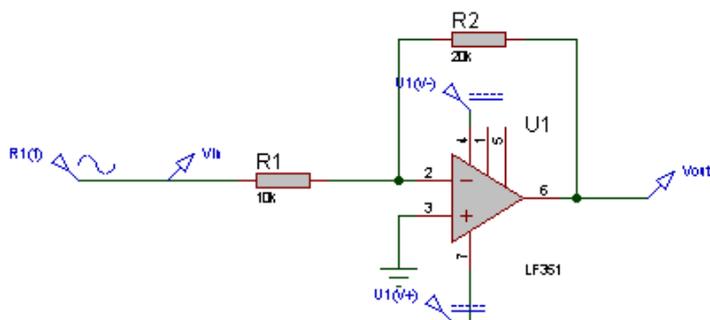
## Simulazione delle principali applicazioni dell'amplificatore operazionale differenziale

**Obiettivo:** Studiare e simulare le applicazioni dell'amplificatore operazionale differenziale ad anello chiuso utilizzando lo strumento di simulazione ISIS Proteus, confrontando i due componenti 741 e LF351.

**Configurazioni studiate:** Amplificatore invertente/non invertente, Buffer (o inseguitore di tensione), Differenziale (con varie impostazioni di resistenze), Sommatore invertente/non invertente, Convertitore V/I, Convertitore I/V invertente/non invertente, Derivatore invertente ideale/reale, Integratore invertente ideale/reale.

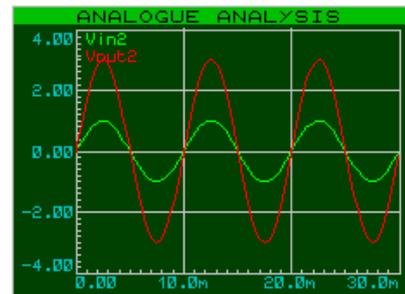
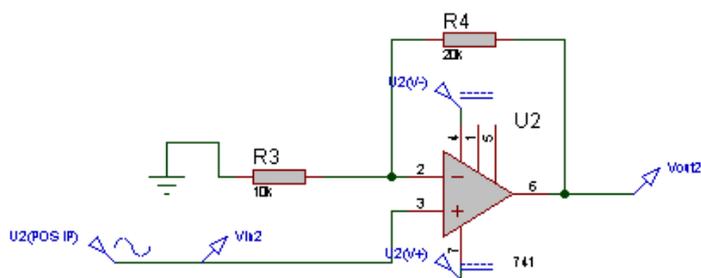
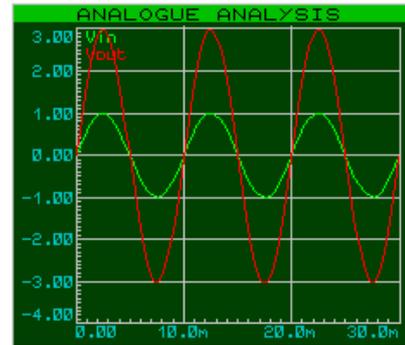
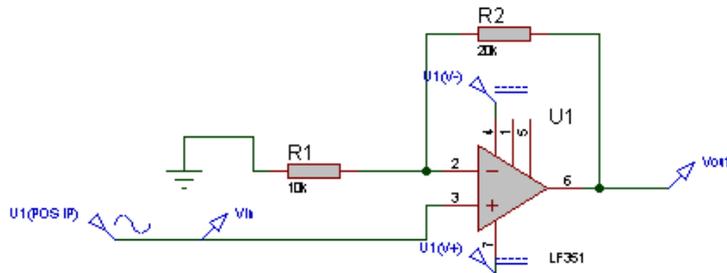
Nota: I segnali di ingresso sono sempre sinusoidi di frequenza 100Hz. Lo studio in frequenza sarà oggetto di studio nelle relazioni future.

## 1) Amplificatore invertente



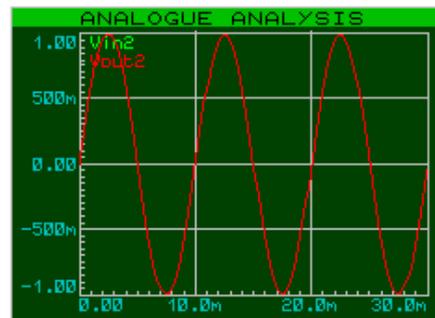
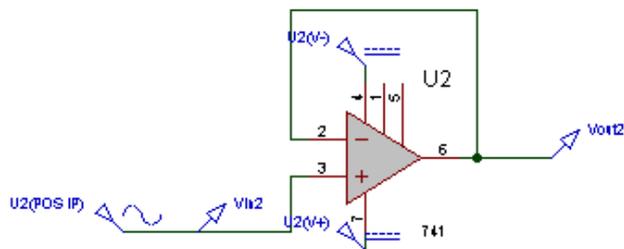
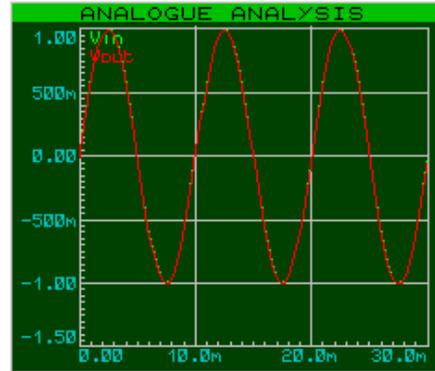
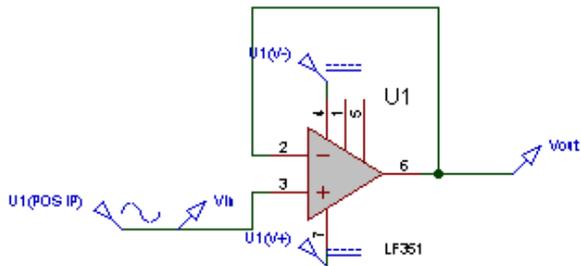
$$v_{out}(t) = -\frac{R2}{R1} \cdot v_{in}(t)$$

## 2) Amplificatore non invertente



$$v_{out}(t) = \left(1 + \frac{R2}{R1}\right) \cdot v_{in}(t)$$

### 3) Buffer

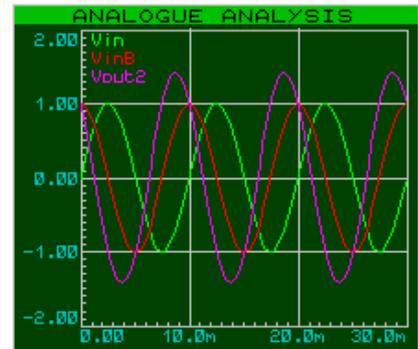
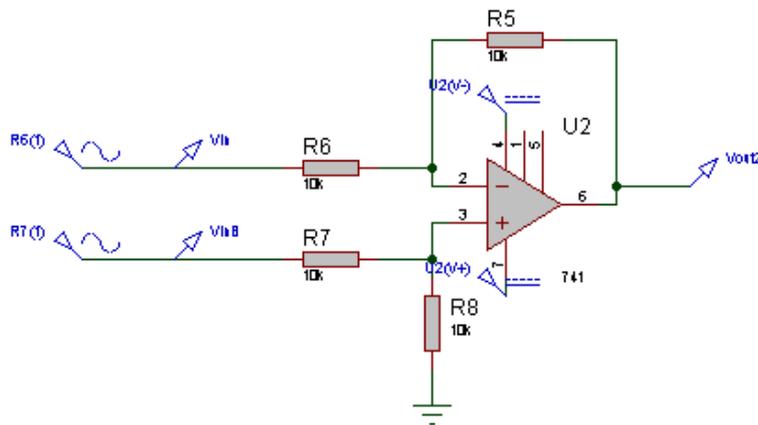
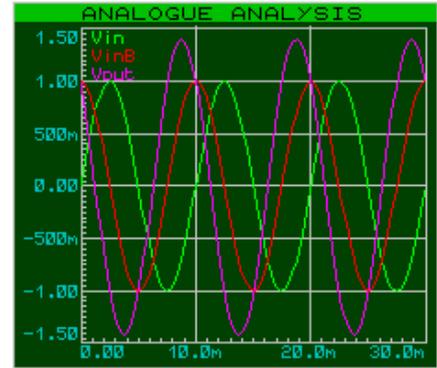
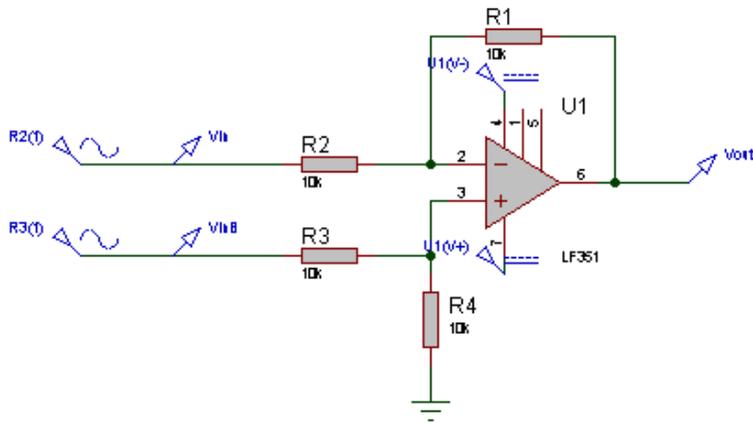


(nota: i due segnali di ingresso e di uscita coincidono)

$$v_{out}(t) = v_{in}(t)$$

( $G \sim 1$ )

4.1) Differenziale (resistenze uguali)

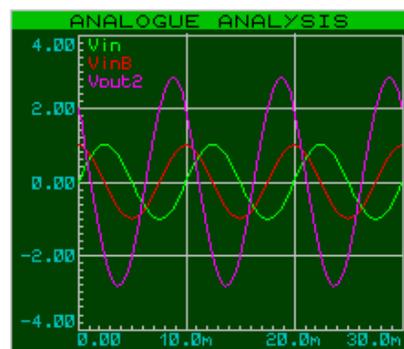
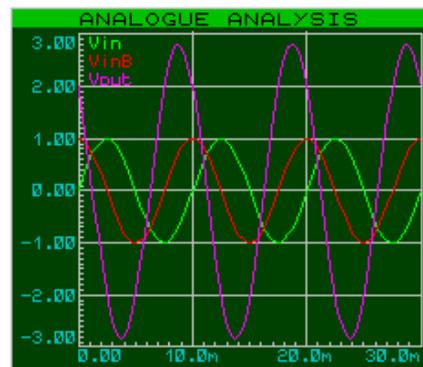
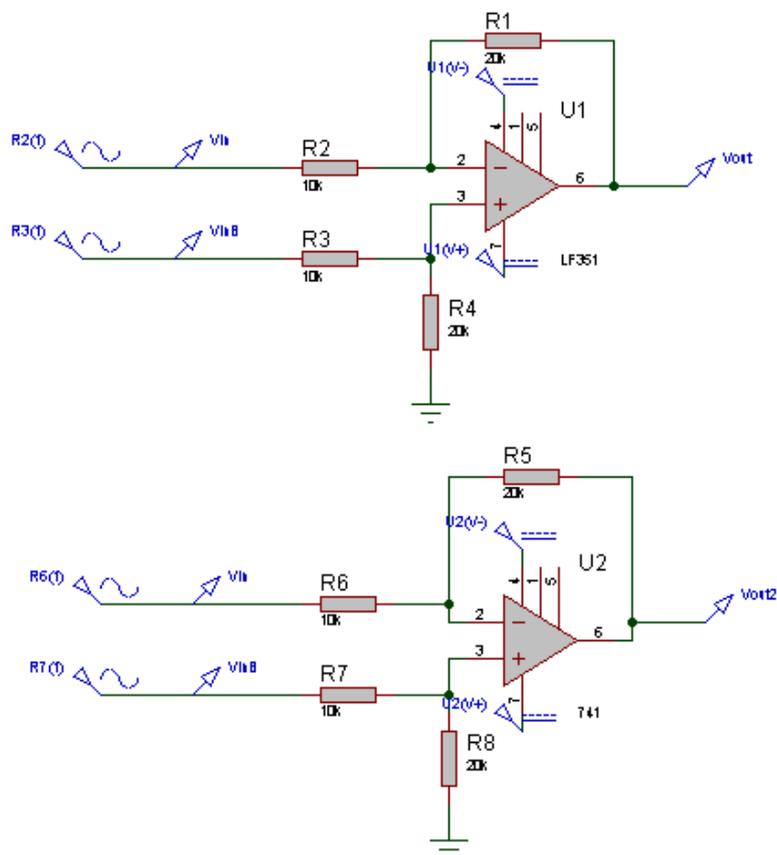


$$v_{out}(t) = v_{inB}(t) - v_{in}(t)$$

Nota: Talvolta l'uscita supera gli ingressi perchè questi, essendo sfasati, creano una situazione in cui  $V_{inB}$  è positivo e  $V_{in}$  è negativo e la differenza viene maggiore del massimo di  $V_{inB}$ .

Analogamente, quando si ha la situazione opposta ( $V_{inB} < 0$  e  $V_{in} > 0$ ) l'uscita è minore del minimo di entrambi i segnali.

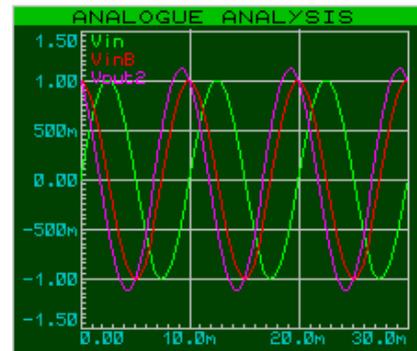
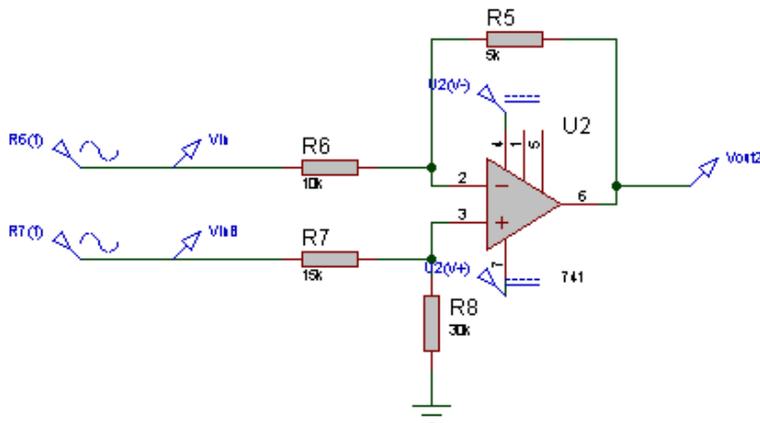
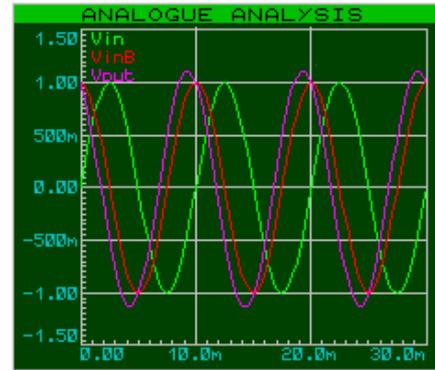
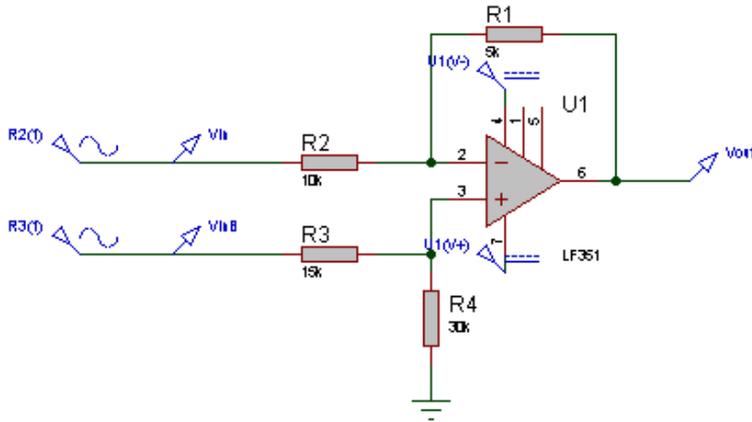
4.2) Differenziale (resistenze uguali a coppie)



$$v_{out}(t) = \frac{R1}{R2} \cdot (v_{inB}(t) - v_{inA}(t))$$

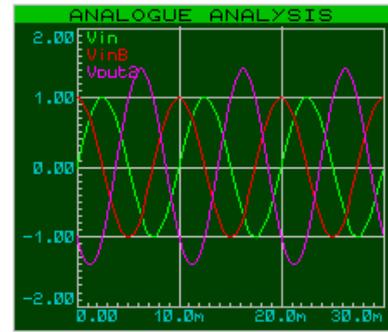
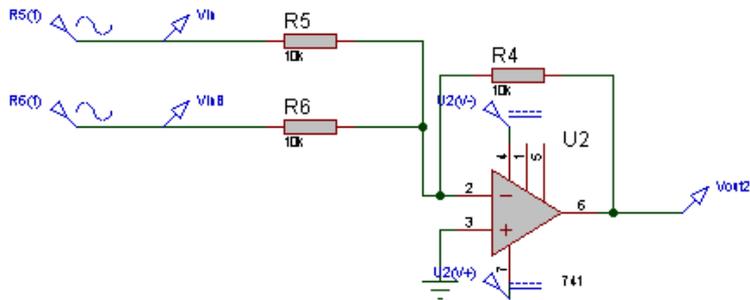
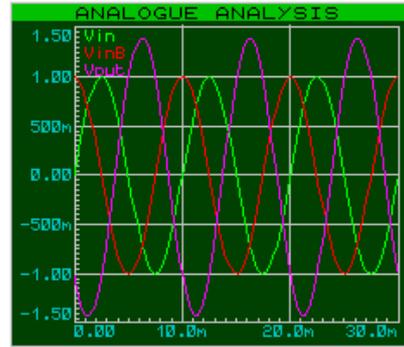
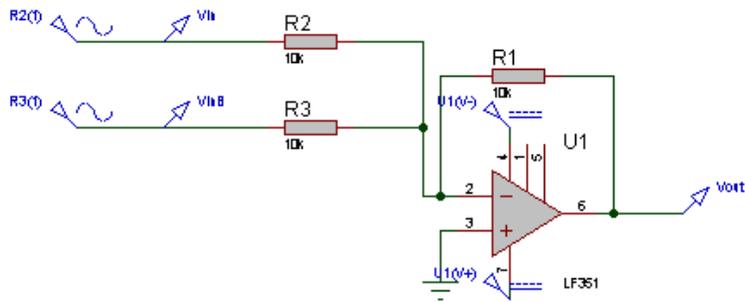
In questo caso

4.3) Differenziale (resistenze diverse)



$$v_{out}(t) = \frac{R1 + R2}{R2} \cdot \frac{R4}{R4 + R3} \cdot v_{inB}(t) - \frac{R1}{R2} \cdot v_{in}(t)$$

5) Sommatore invertente

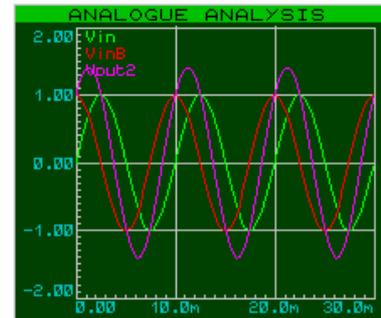
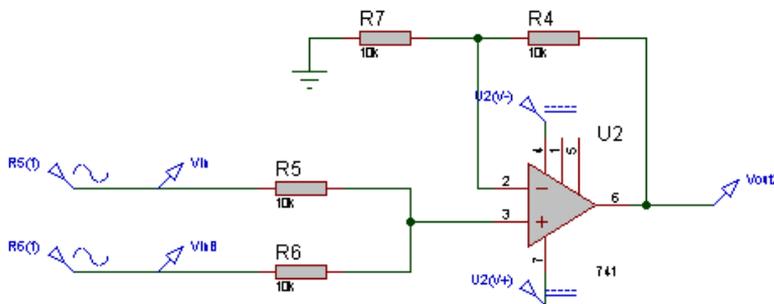
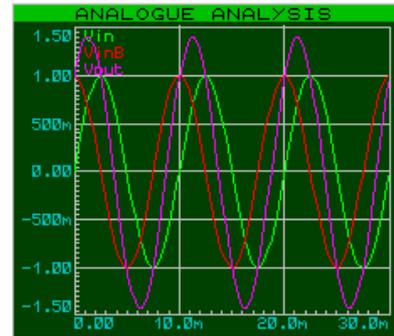
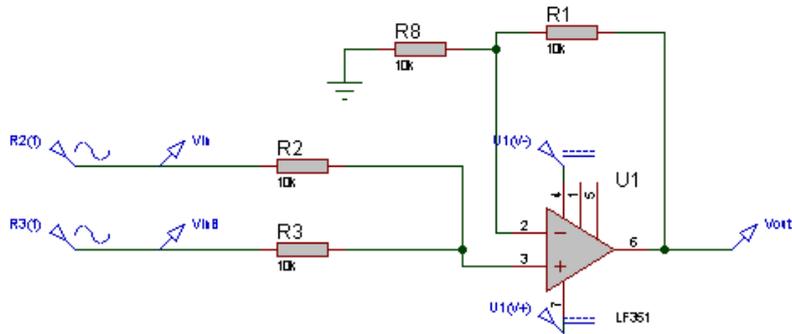


$$v_{out}(t) = -R1 \cdot \left( \frac{v_{inA}(t)}{R2} + \frac{v_{inB}(t)}{R3} \right)$$

se  $R2=R3$  (come in questo caso)

$$v_{out}(t) = -\frac{R1}{R2} \cdot (v_{inA}(t) + v_{inB}(t))$$

6) Sommatore non invertente



$$v_{out}(t) = \left(1 + \frac{R1}{R8}\right) \cdot \left( v_{inA}(t) \cdot \frac{R2}{R2 + R3} + v_{inB}(t) \cdot \frac{R3}{R2 + R3} \right)$$

In questo caso  $R1=R8=R2=R3$ , quindi

$$1 + \frac{R1}{R8} = 2$$

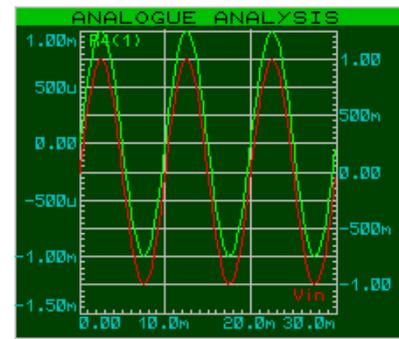
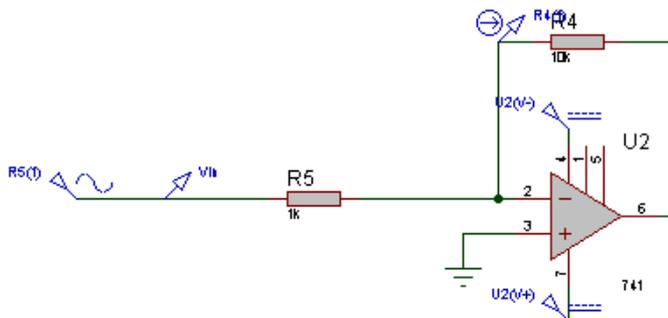
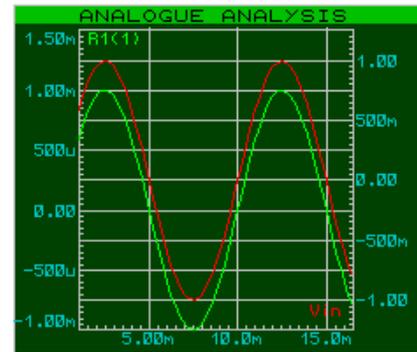
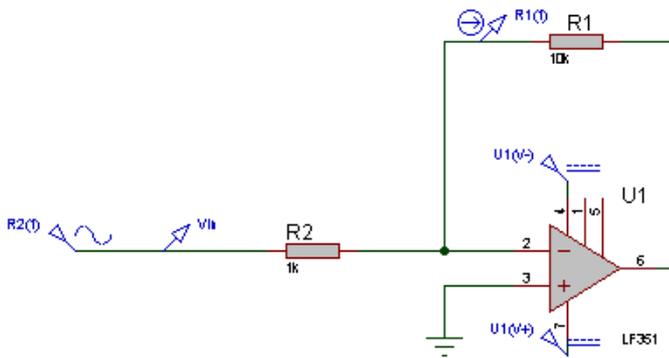
$$\frac{R2}{R2 + R3} = \frac{1}{2}$$

$$\frac{R3}{R2 + R3} = \frac{1}{2}$$

quindi

$$v_{out}(t) = 2 \cdot \left( \frac{v_{inA}(t) + v_{inB}(t)}{2} \right) = v_{inA}(t) + v_{inB}(t)$$

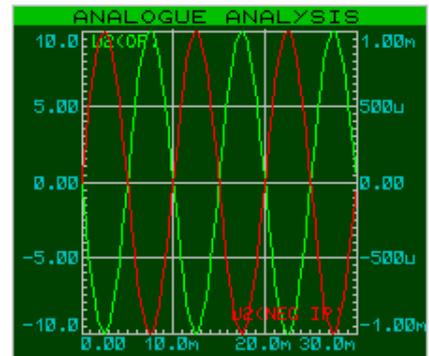
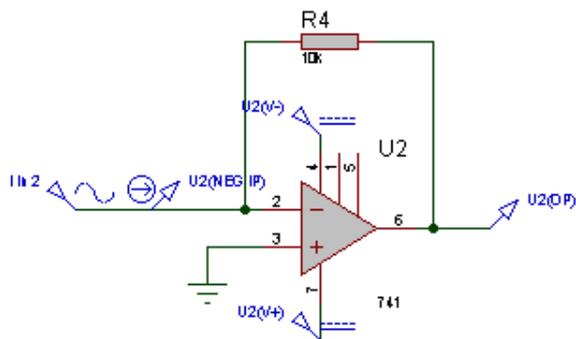
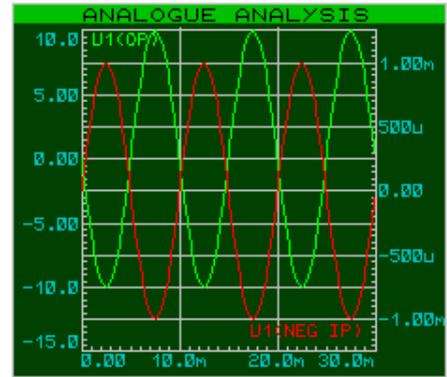
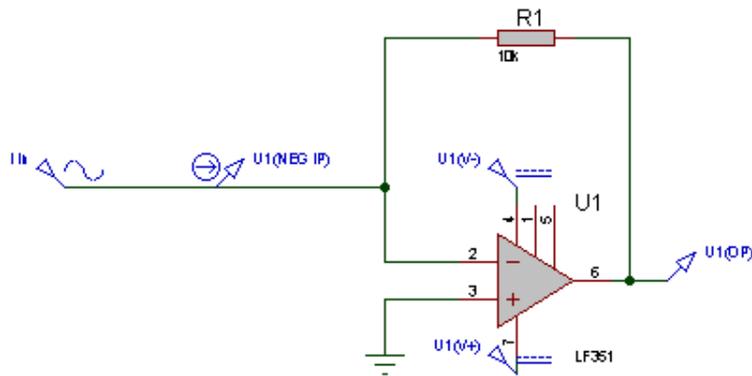
## 7) Convertitore V-I



$$i_{out}(t) = \frac{v_{out}(t)}{R2}$$

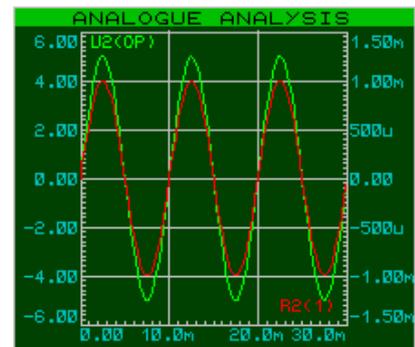
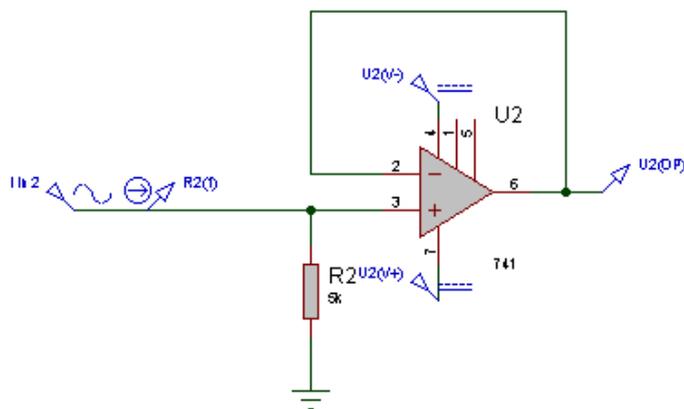
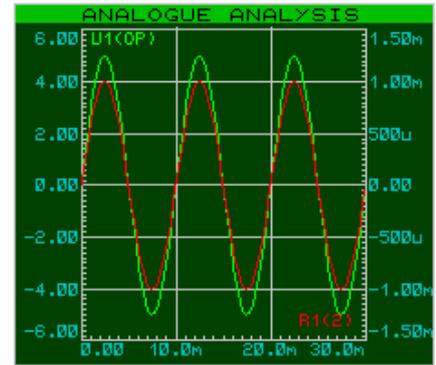
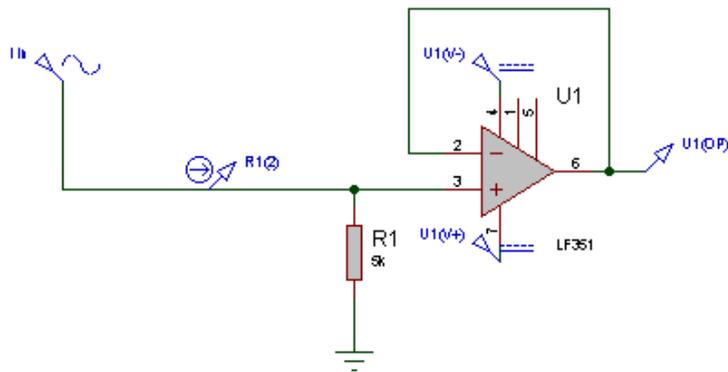
Nota: la cosa interessante è che la corrente non dipende dalla R1. La tensione massima e quella minima che potranno cadere sul carico saranno dipendenti dall'alimentazione.

8.1) Convertitore I-V invertente



$$v_{out}(t) = -R1 \cdot i_{in}(t)$$

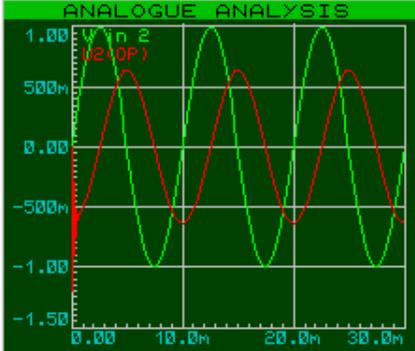
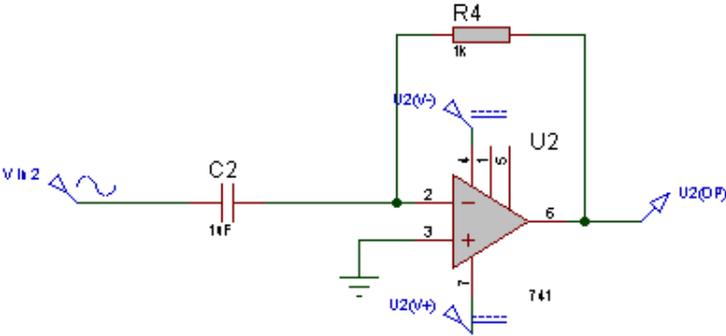
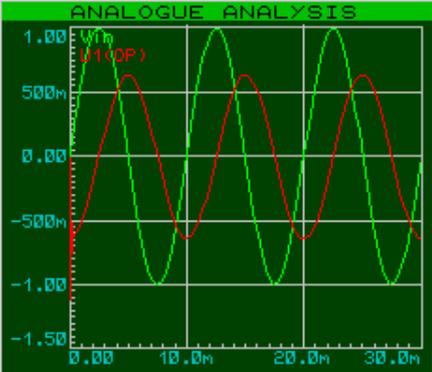
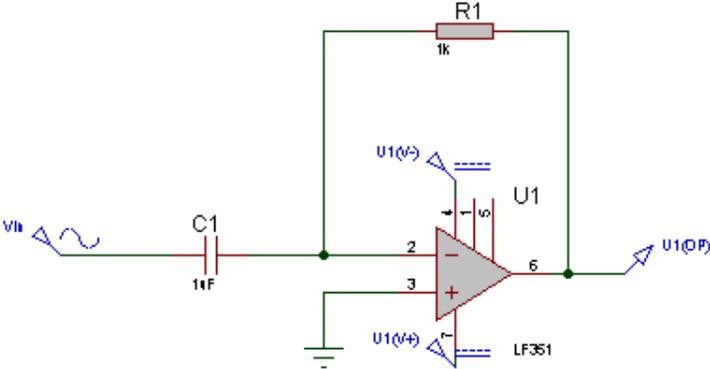
8.2) Convertitore I-V non invertente



$$v_{out}(t) = R1 \cdot i_{in}(t)$$

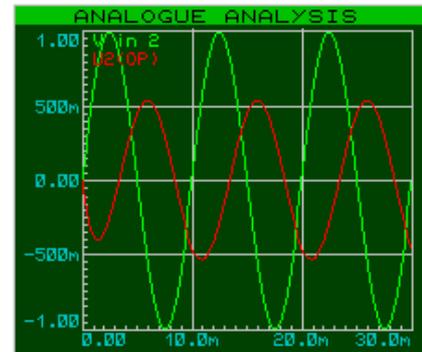
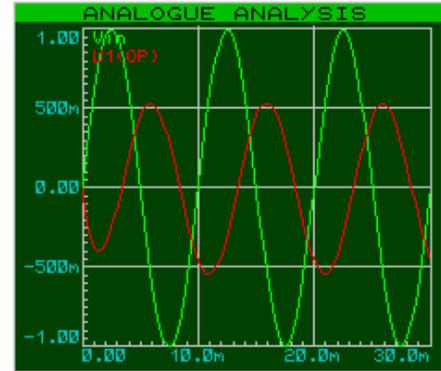
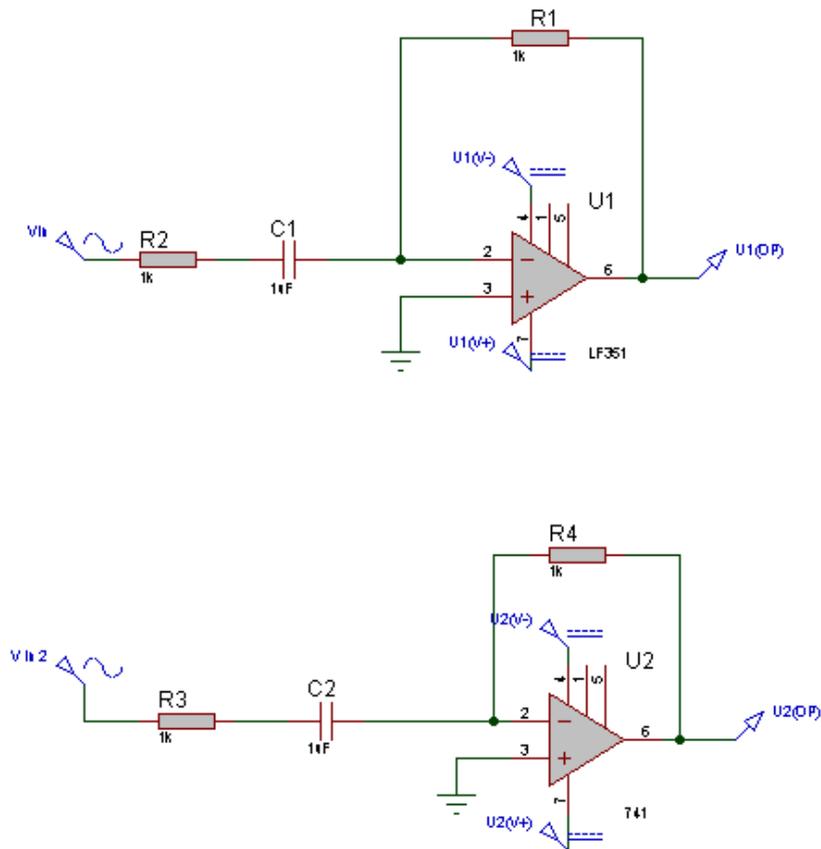
Nota: si sfrutta la caratteristica da buffer, riportando la tensione che cade sulla resistenza in uscita

9) Derivatore ideale invertente



$$v_{out}(t) = -R \cdot C \cdot \frac{dv_{in}(t)}{dt}$$

## 10) Derivatore reale invertente

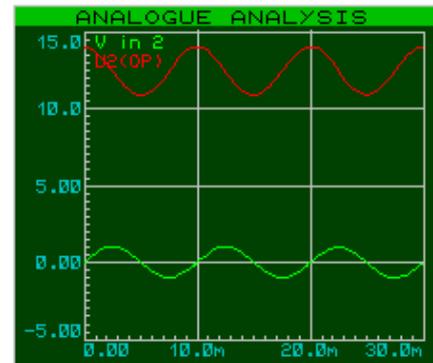
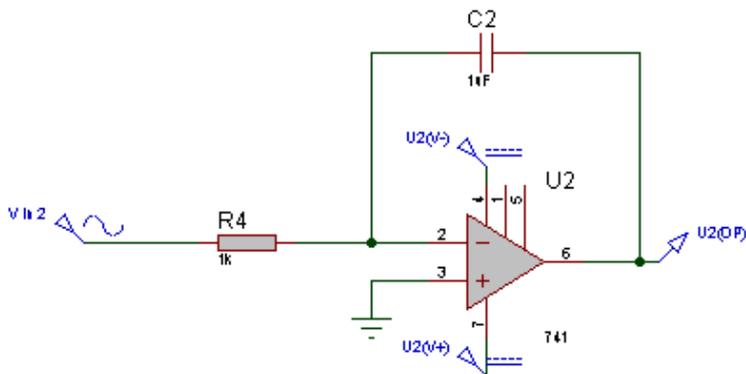
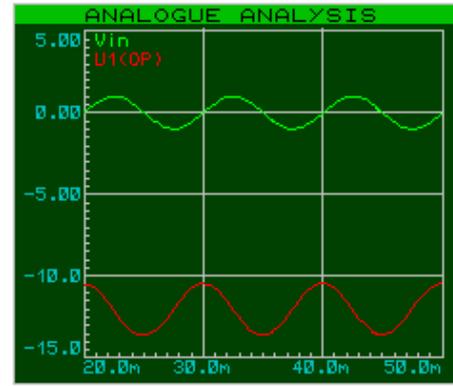
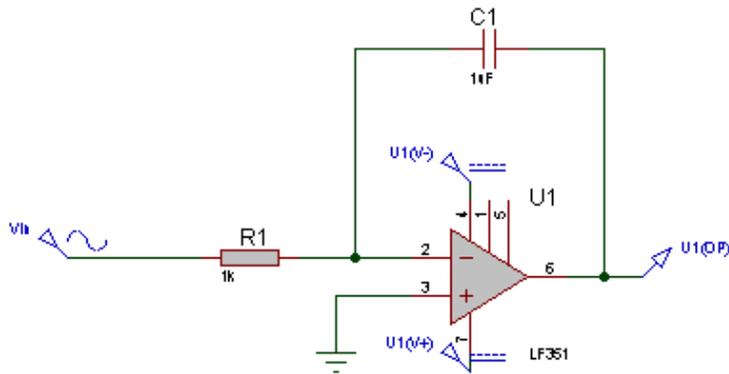


$$|V_{out}(j\omega)| = -\frac{R_1}{\sqrt{R_2^2 + \left(\frac{1}{\omega \cdot C}\right)^2}} \cdot |V_{in}(j\omega)|$$

$$\varphi_{vout} = \varphi_{vin} + \arctg(0) - \arctg\left(\frac{1}{\omega R_2 \cdot C}\right)$$

Il circuito presenta una fase di transitorio senza oscillazioni, a differenza del derivatore ideale.

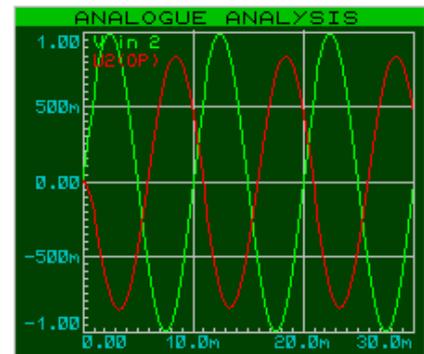
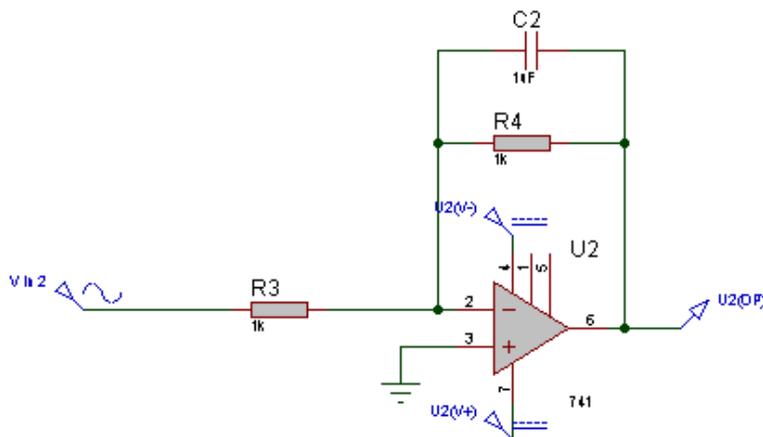
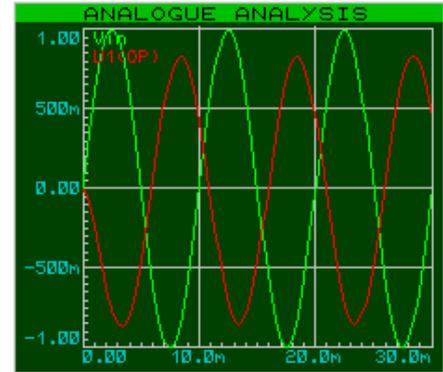
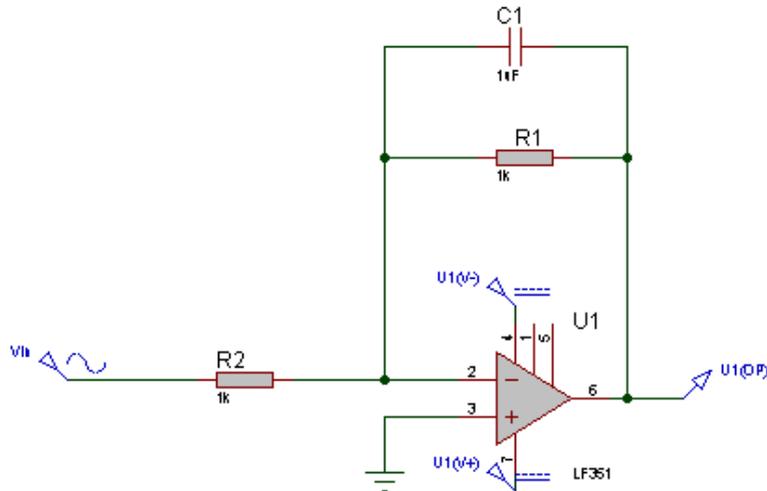
## 11) Integratore ideale invertente



$$v_{out}(t) = -\frac{1}{R1 \cdot C} \cdot \int v_{in}(t) dt$$

Nota: è interessante notare che l'offset con il 741 sia positivo (con valore massimo la soglia positiva dipendente dall'alimentazione) mentre con l'LF351 sia negativo.

## 12) Integratore reale invertente



$$|V_{out}(j\omega)| = -\frac{\left(\frac{R1}{\omega C}\right)^2}{\sqrt{R1^2 + \left(\frac{1}{\omega \cdot C}\right)^2}} \cdot \frac{|V_{in}(j\omega)|}{R2}$$

$$\varphi_{vout} = \varphi_{vin} + \arctg\left(\frac{R1}{\omega C}\right) - \arctg\left(\frac{1}{\omega R1 \cdot C}\right)$$

$$\varphi_{vout} = \varphi_{vin} + \frac{\pi}{2} - \arctg\left(\frac{1}{\omega R1 \cdot C}\right)$$

### Conclusioni:

Simulando le varie configurazioni abbiamo trovato un riscontro con le formule teoriche con a volte alcune piccole variazioni. Queste variazioni sono dovute al fatto che il simulatore ISIS tiene conto anche di fattori quali capacità e correnti parassite, trascurate in teoria.

Combinando queste applicazioni dell'amplificatore operazionale possiamo potenzialmente sviluppare la maggior parte delle funzioni matematiche e progettare (come vedremo nella prossima relazione) circuiti di condizionamento di segnali analogici.

Lavorando con guadagni relativamente bassi e a frequenza di 100Hz, non abbiamo riscontrato problemi di attenuazione da parte del componente. Pertanto i due componenti studiati, 741 e LF351, non presentano quasi mai grandi differenze.