LTspice
Forme d'onda dei generatori

www.die.ing.unibo.it/pers/mastri/didattica.htm
(versione del 27-2-2016)

Forme d'onda disponibili

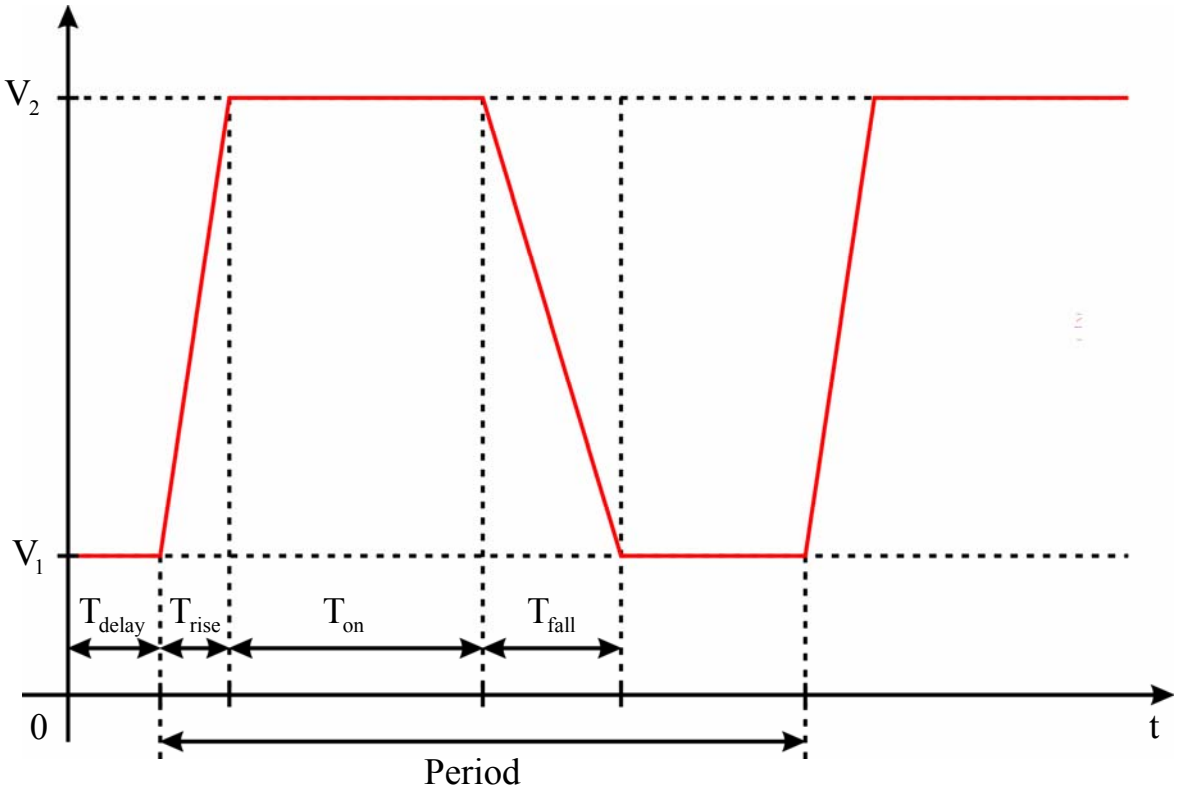
- Nell'analisi nel dominio del tempo Spice mette a disposizione, sia per i generatori di tensione che per quelli di corrente, le seguenti forme d'onda
  - **Pulse**: impulso trapezoidale
  - **Sine**: finzione sinusoidale smorzata
  - **Exp**: impulso esponenziale
  - **SFFM** (Single-Frequency Frequency Modulation): portante sinusoidale modulata in frequenza da un segnale sinusoidale
  - **PWL** (Piecewise linear): funzione lineare a tratti
- In seguito si farà riferimento ai generatori di tensione (per i generatori di corrente si usano parametri analoghi)

Pulse

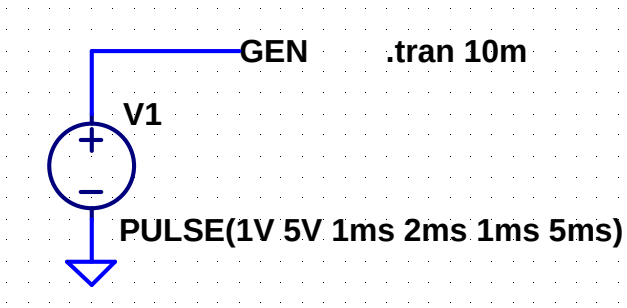
Nome	Parametro	Val. predefinito
V_1	valore iniziale (V)	0
V_2	valore finale dell'impulso (V)	0
T_{delay}	ritardo (s)	0
T_{rise}	tempo di salita (s)	T_{step}
T_{fall}	tempo di discesa (s)	T_{step}
T_{on}	durata dell'impulso (s)	T_{stop}
Period	periodo (s)	T_{stop}
N_{cycles}	numero di periodi	non limitato

T_{stop} è l'istante finale dall'analisi
T_{step} è il tempo di campionamento utilizzato del programma per tracciare i grafici

Pulse – Forma d'onda



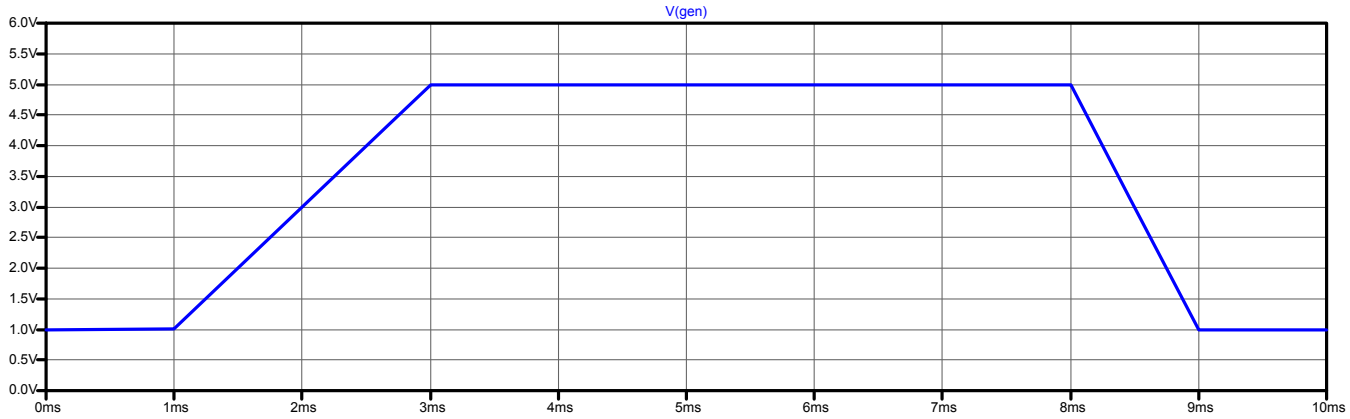
Pulse – Esempio 1



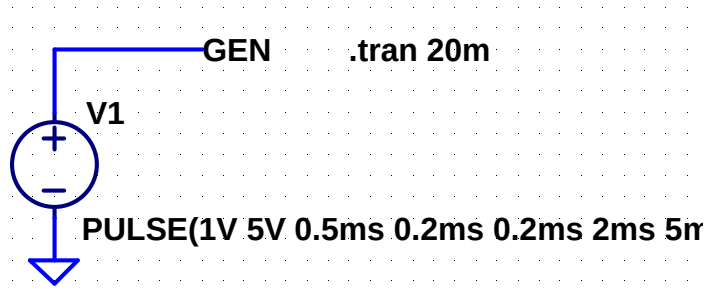
$V_1 = 1\,V$ $T_{rise} = 2\,ms$

$V_2 = 5\,V$ $T_{fall} = 1\,ms$

$T_{delay} = 1\,ms$ $T_{on} = 5\,ms$



Pulse – Esempio 2

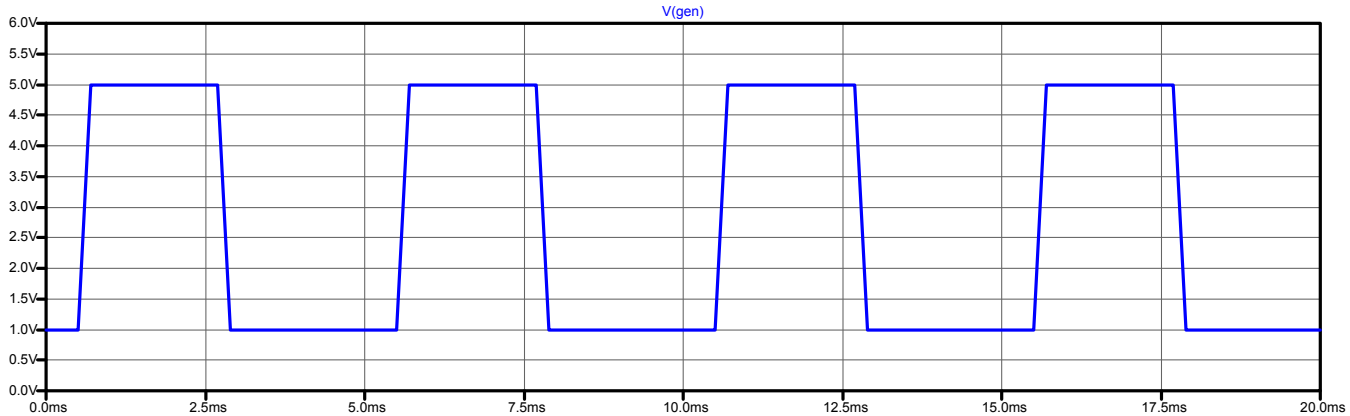


$V_1 = 1\,V$ $T_{fall} = 0.2\,ms$

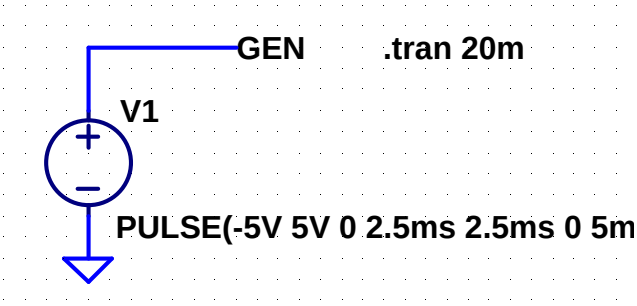
$V_2 = 5\,V$ $T_{on} = 2\,ms$

$T_{delay} = 0.5\,ms$ $T_{period} = 5\,ms$

$T_{rise} = 0.2\,ms$



Pulse – Esempio 3

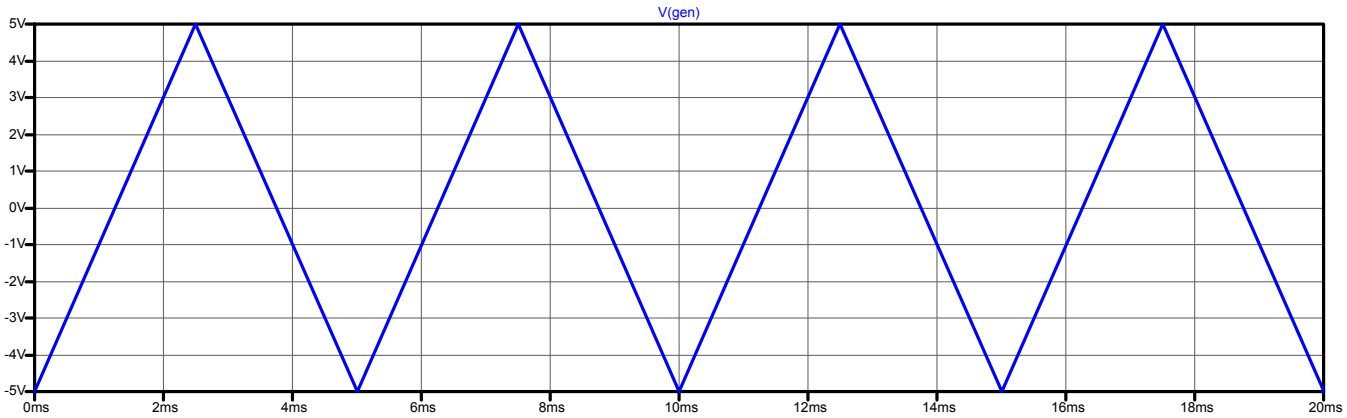


$V_1 = -5\,V$ $\quad T_{fall} = 2.5\,ms$

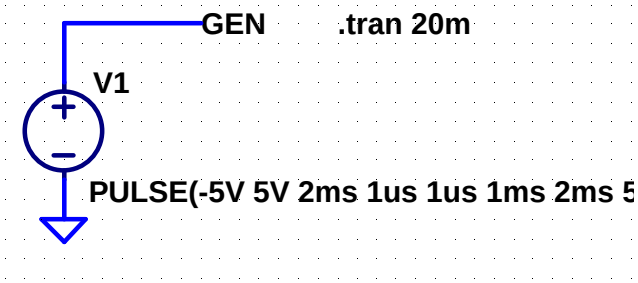
$V_2 = 5\,V$ $\quad T_{on} = 0\,s$

$T_{delay} = 0\,s$ $\quad T_{period} = 5\,ms$

$T_{rise} = 2.5\,ms$



Pulse – Esempio 4

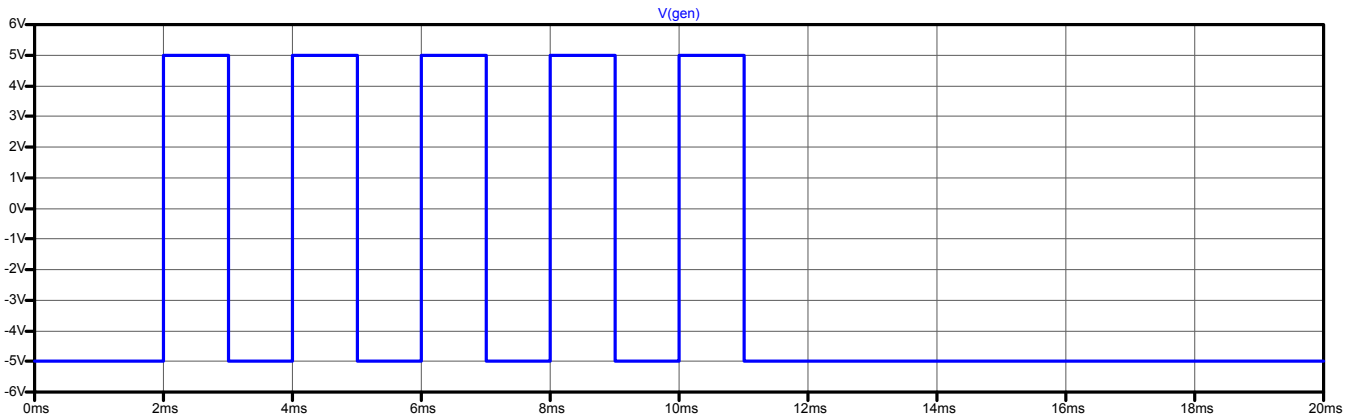


$V_1 = -5\,V$ $\quad T_{fall} = 1\,\mu s$

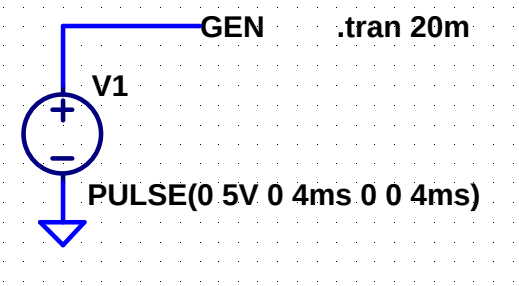
$V_2 = 5\,V$ $\quad T_{on} = 1\,ms$

$T_{delay} = 2\,ms$ $\quad T_{period} = 2\,ms$

$T_{rise} = 1\,\mu s$ $\quad N_{cycles} = 5$



Pulse – Esempio 5

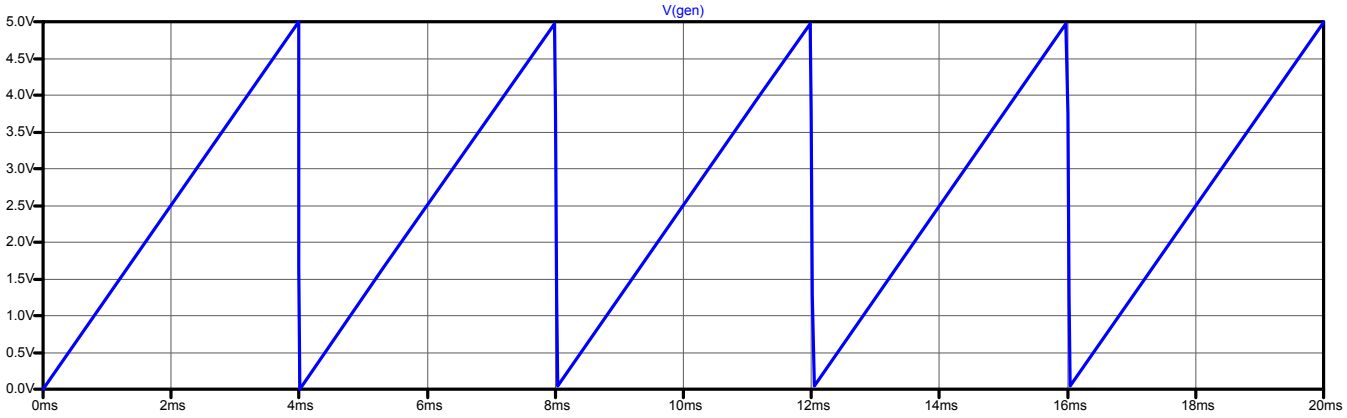


$V_1 = 0\,V$ $\quad T_{fall} = 0\,s$

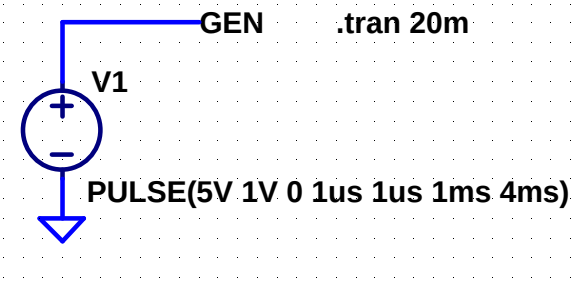
$V_2 = 5\,V$ $\quad T_{on} = 0\,s$

$T_{delay} = 0\,s$ $\quad T_{period} = 4\,ms$

$T_{rise} = 4\,ms$



Pulse – Esempio 6

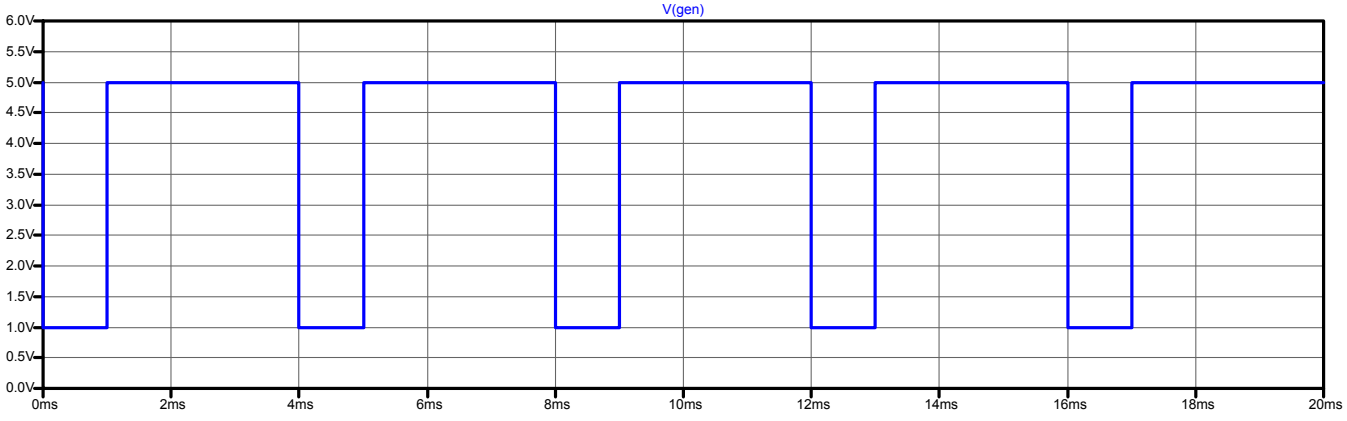


$V_1 = 5\,V$ $\quad T_{fall} = 1\,\mu s$

$V_2 = 1\,V$ $\quad T_{on} = 1\,mS$

$T_{delay} = 0\,s$ $\quad T_{period} = 4\,ms$

$T_{rise} = 1\,\mu s$

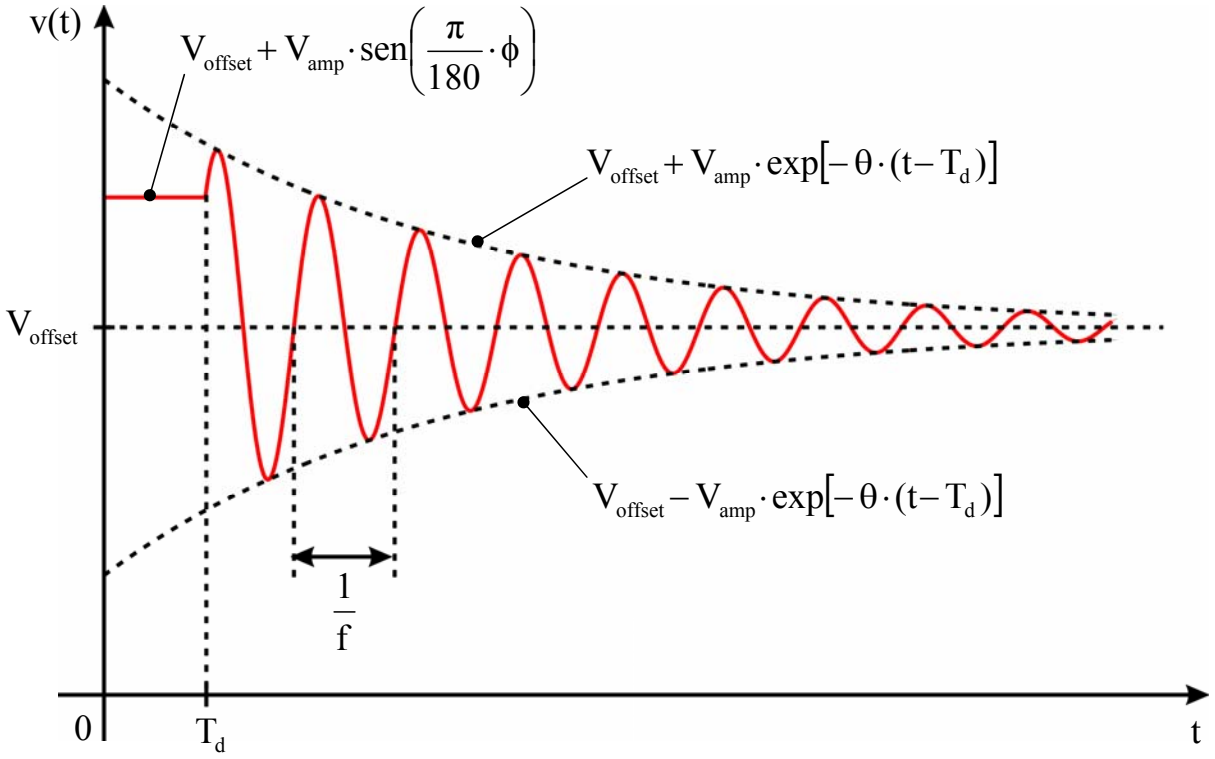


Sine

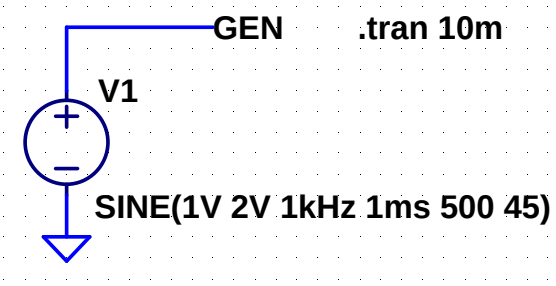
Nome	Parametro	Val. predefinito
V_{offset}	offset (V)	0
V_{amp}	ampiezza (V)	0
f	frequenza (Hz)	$1 / T_{stop}$
T_d	ritardo (s)	0
θ	coefficiente di smorzamento (s^{-1})	0
ϕ	fase (gradi)	0
N_{cycles}	numero di periodi	non limitato

$$v(t) = \begin{cases} V_{offset} + V_{amp} \cdot \text{sen}\left(\frac{\pi}{180} \cdot \phi\right) & \text{per } t \le T_d \\ V_{offset} + V_{amp} \cdot \exp[-\theta \cdot (t - T_d)] \cdot \text{sen}\left[2\pi \cdot f \cdot (t - T_d) + \frac{\pi}{180} \cdot \phi\right] & \text{per } t > T_d \end{cases}$$

Sine – Forma d'onda



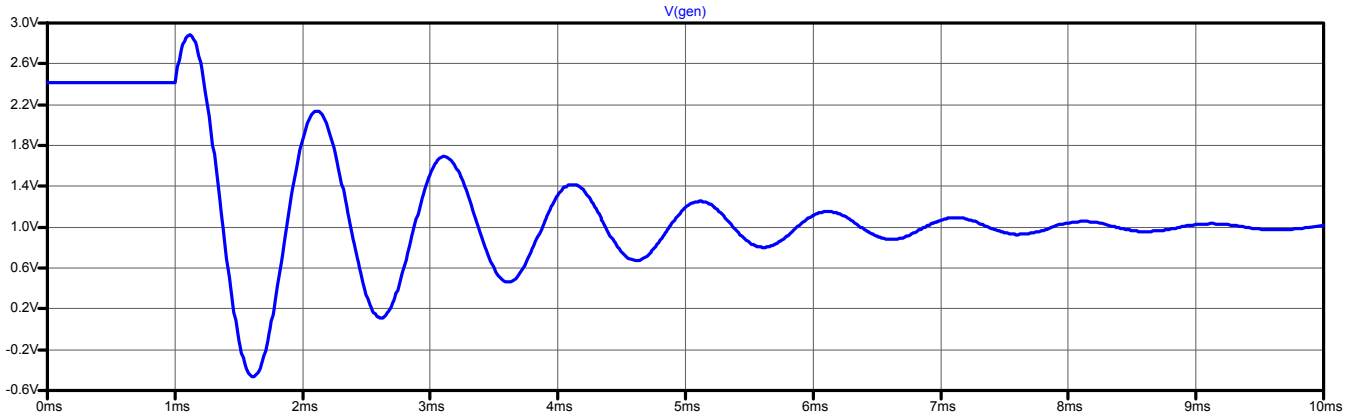
Sine – Esempio 1



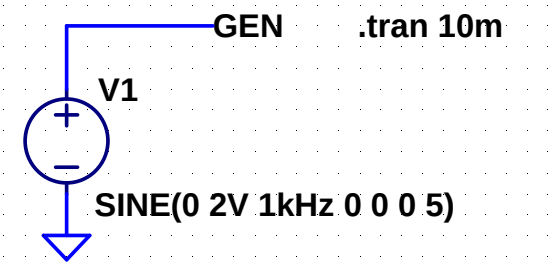
$V_{offset} = 1\,V \qquad T_d = 1\,ms$

$V_{amp} = 2\,V \qquad \theta = 500\,s^{-1}$

$f = 1\,kHz \qquad \phi = 45°$



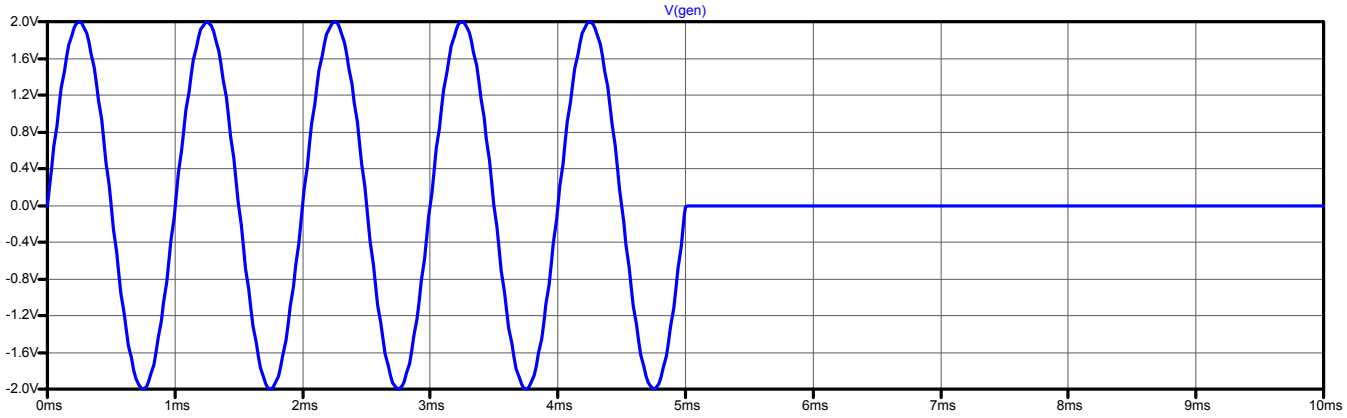
Sine – Esempio 2



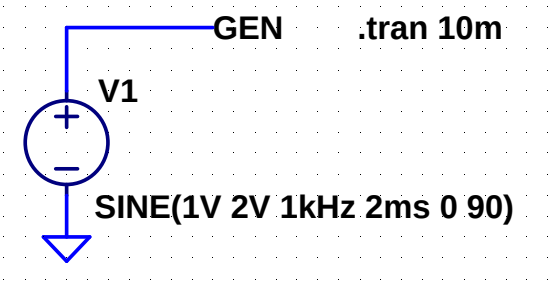
$V_{offset} = 0\,V \qquad T_d = 0\,s \qquad N_{cycles} = 5$

$V_{amp} = 2\,V \qquad \theta = 0\,s^{-1}$

$f = 1\,kHz \qquad \phi = 0°$



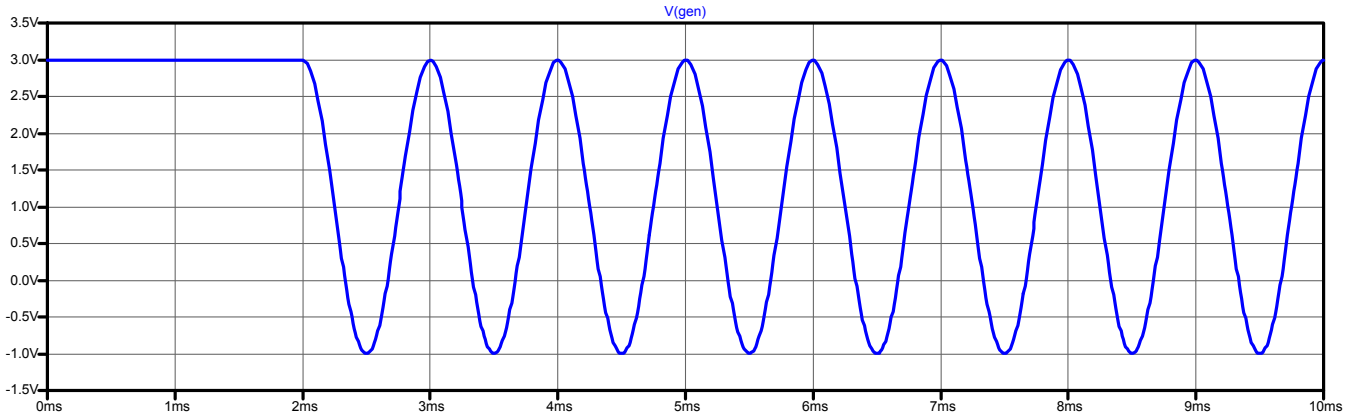
Sine – Esempio 3



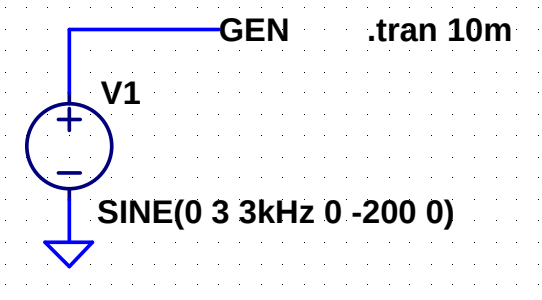
$V_{offset} = 1\,V$ $\quad T_d = 2\,ms$

$V_{amp} = 2\,V$ $\quad \theta = 0\,s^{-1}$

$f = 1\,kHz$ $\quad \phi = 90°$



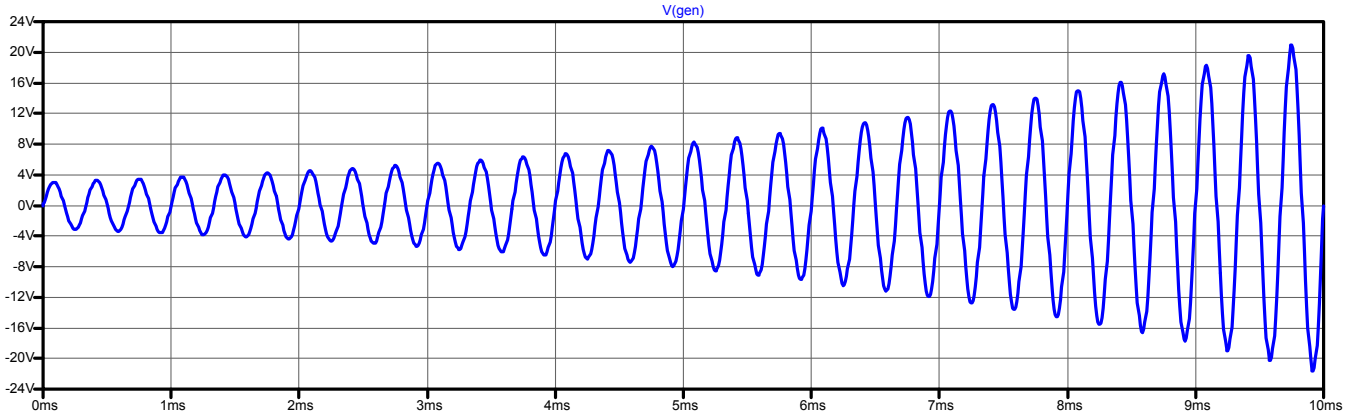
Sine – Esempio 4



$V_{offset} = 0\,V$ $\quad T_d = 0\,ms$

$V_{amp} = 3\,V$ $\quad \theta = -200\,s^{-1}$

$f = 3\,kHz$ $\quad \phi = 0°$

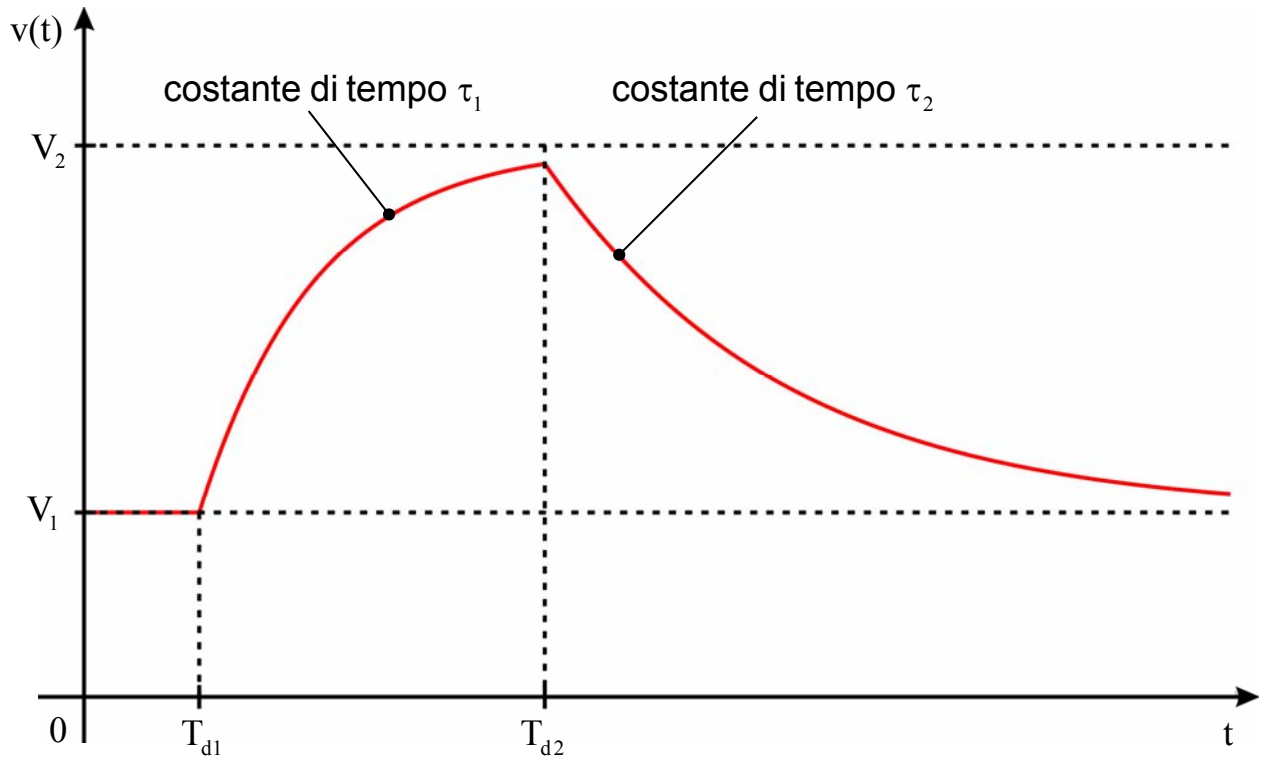


Exp

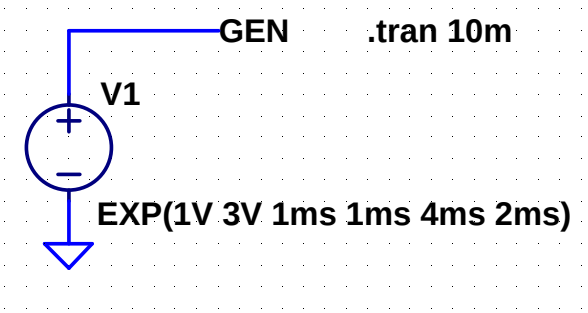
Nome	Parametro	Val. predefinito
V_1	valore iniziale (V)	0
V_2	valore finale dell'impulso (V)	0
T_{d1}	ritardo del fronte di salita(s)	0
τ_1	costante di tempo di salita(s)	T_{step}
T_{d2}	ritardo del fronte di discesa(s)	$T_{d1} + T_{step}$
τ_2	costante di tempo di discesa(s)	T_{step}

$$v(t) = \begin{cases} V_1 & \text{per } t \le T_{d1} \\ v_1(t) = V_1 + (V_2 - V_1) \cdot \{1 - \exp[-(t - T_{d1})/\tau_1]\} & \text{per } T_{d1} < t \le T_{d2} \\ v_2(t) = v_1(t) - (V_2 - V_1) \cdot \{1 - \exp[-(t - T_{d2})/\tau_2]\} & \text{per } t > T_{d2} \end{cases}$$

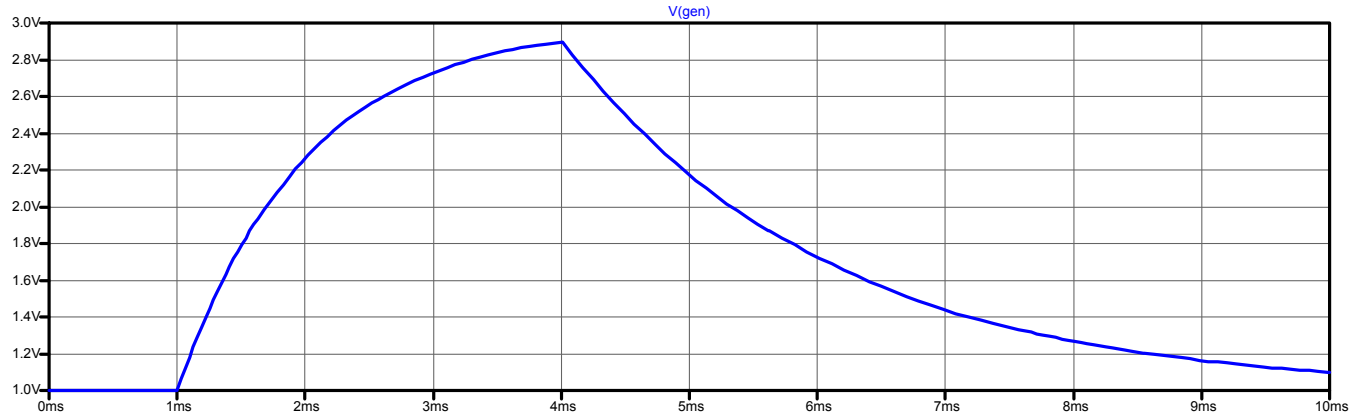
Exp – Forma d'onda



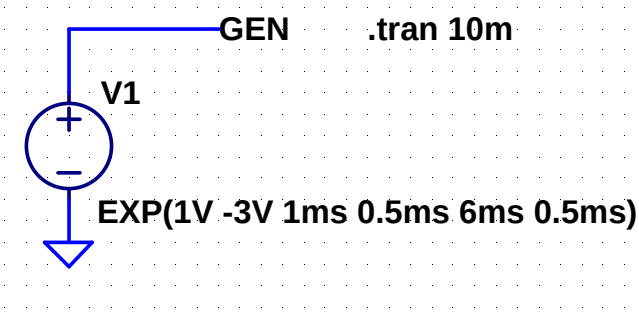
Exp – Esempio 1



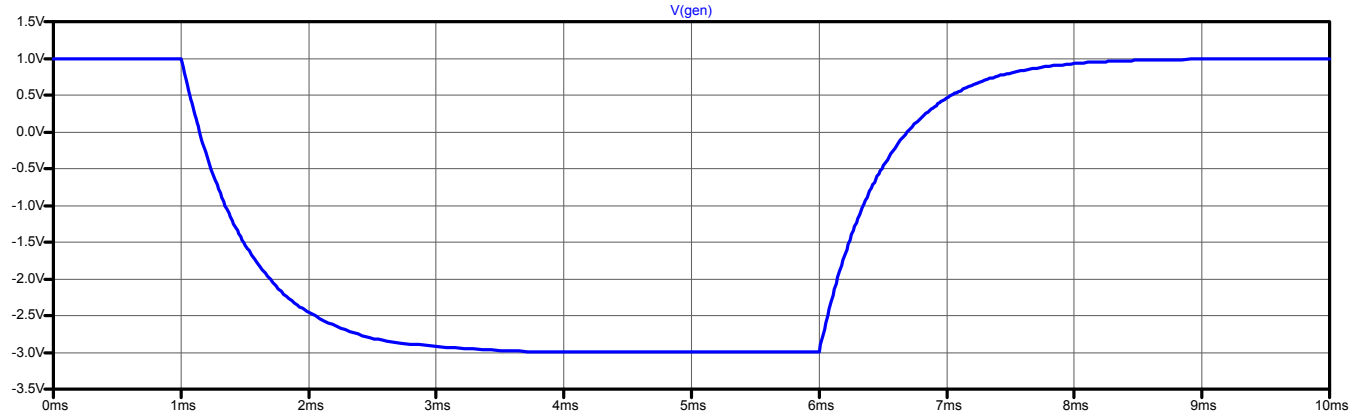
$V_1 = 1\,V \qquad \tau_1 = 1\,ms$
$V_2 = 3\,V \qquad T_{d2} = 4\,ms$
$T_{d1} = 1\,ms \qquad \tau_2 = 2\,ms$



Exp – Esempio 2



$V_1 = 1\,V \qquad \tau_1 = 0.5\,ms$
$V_2 = -3\,V \qquad T_{d2} = 6\,ms$
$T_{d1} = 1\,ms \qquad \tau_2 = 0.5\,ms$

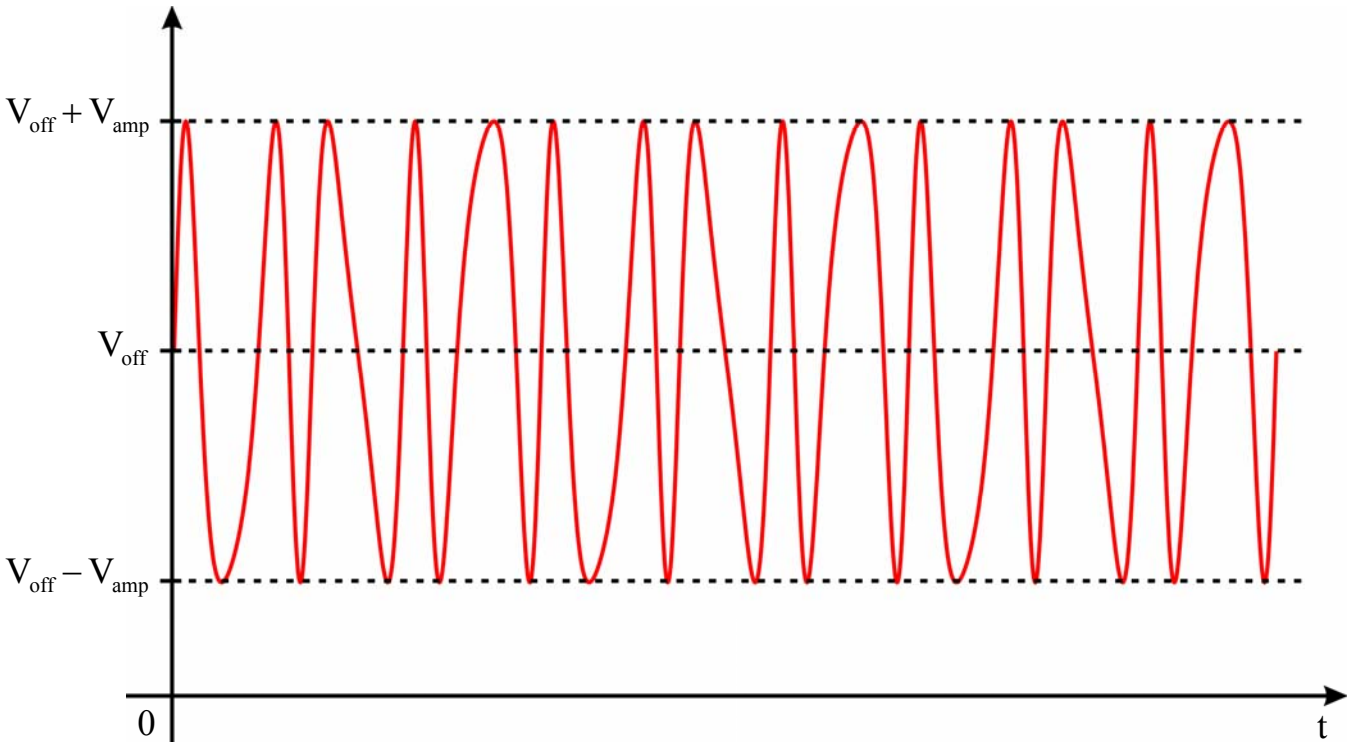


SFFM

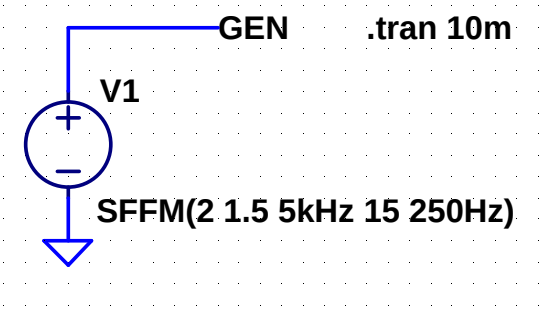
Nome	Parametro	Val. predefinito
V_{off}	offset (V)	0
V_{amp}	ampiezza (V)	0
f_{carr}	frequenza della portante (Hz)	$1 / T_{stop}$
MDI	indice di modulazione	0
f_{sig}	frequenza del segnale (Hz)	$1 / T_{stop}$

$$v(t) = V_{off} + V_{amp} \cdot \text{sen}\left[2\pi \cdot f_{carr} \cdot t + MDI \cdot \text{sen}(2\pi \cdot f_{sig} \cdot t)\right]$$

SFFM – Forma d'onda



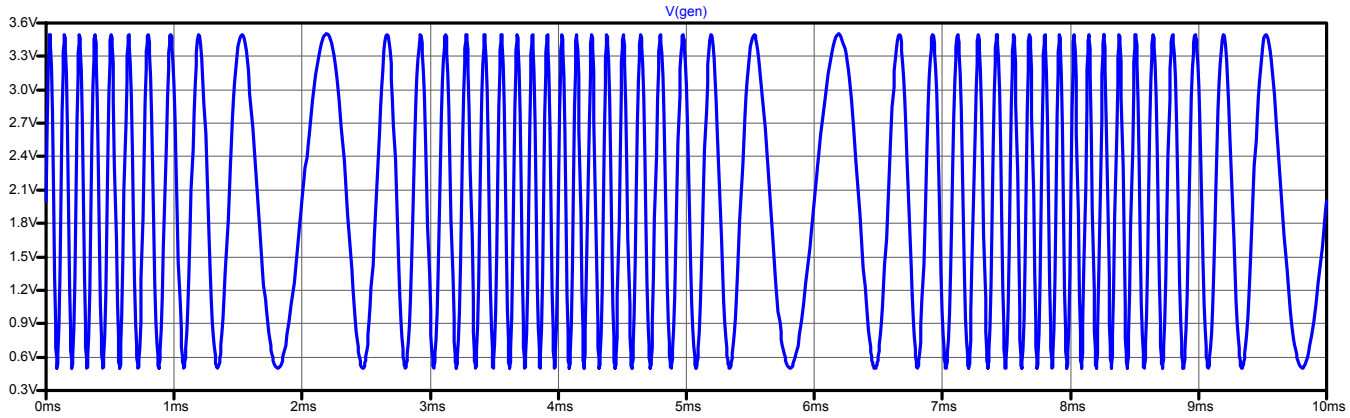
SFFM – Esempio



$V_{off} = 2\,V$ $\quad f_{car} = 5\,kHz$

$V_{amp} = 1.5\,V$ $\quad MDI = 15$

$f_{sig} = 250\,Hz$



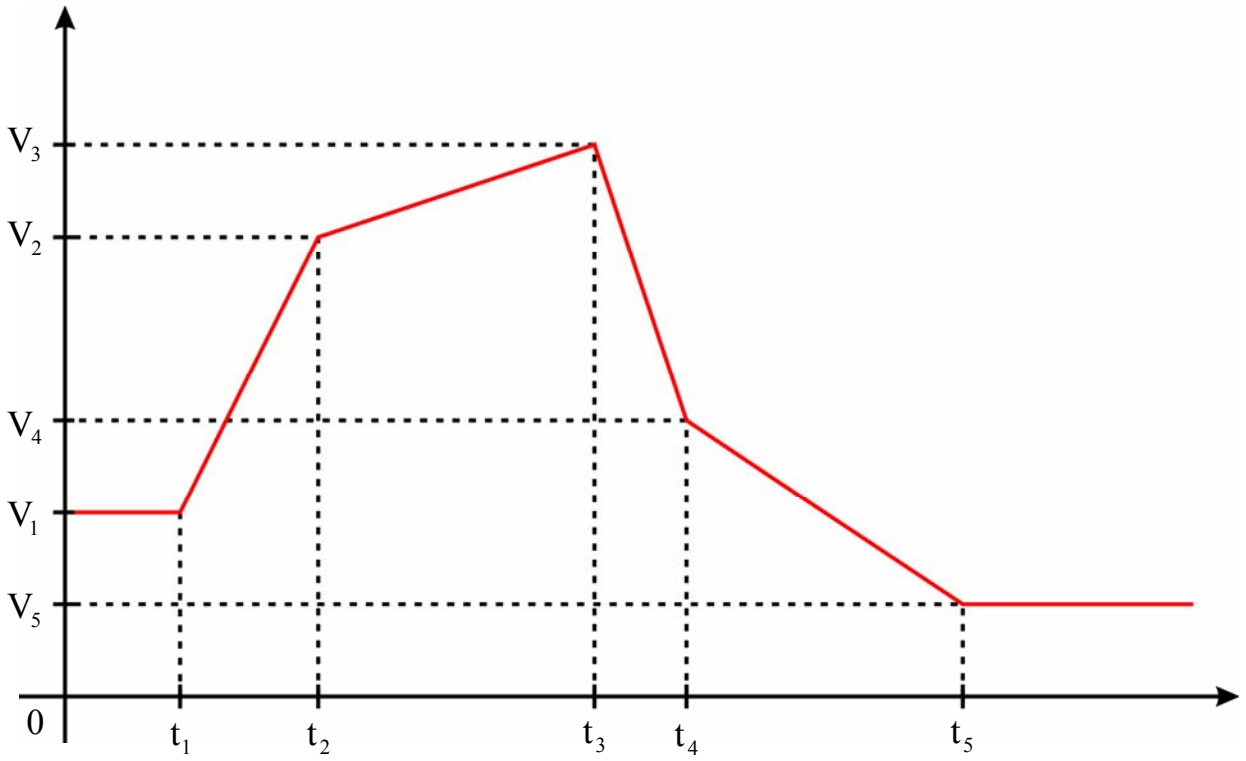
PWL

- Si assegnano, per un numero N arbitrario di punti, i valori di t_i e V_i
- Nell'intervallo t_i, t_{i+1} la tensione è ottenuta mediante interpolazione lineare

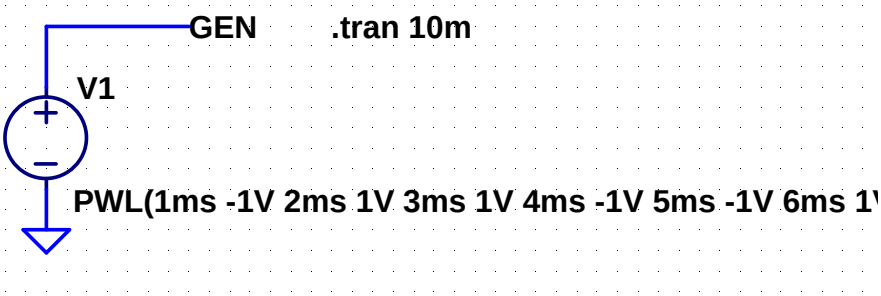
$$v(t) = V_i + \frac{t - t_i}{t_{i+1} - t_i}(V_{i+1} - V_i)$$

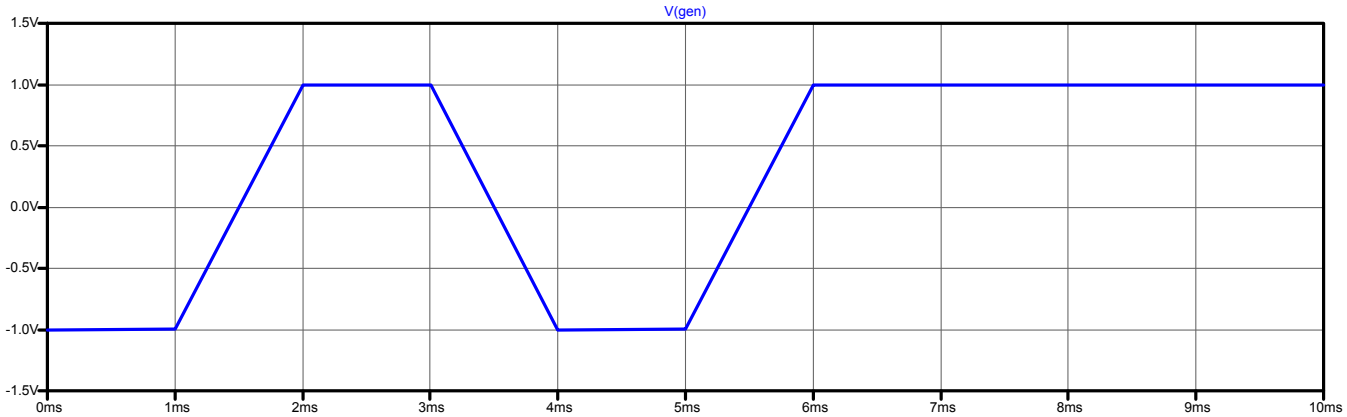
- Se $t_1 > 0$, fra 0 e t_1 la tensione è costante e vale V_1
- Se l'ultimo valore di t assegnato, t_N, è minore di T_{stop} (istante finale della simulazione) fra t_N e T_{stop} la tensione è costante e vale V_N
- I valori di tempo e tensione possono essere forniti anche mediante un file esterno

PWL – Forma d'onda

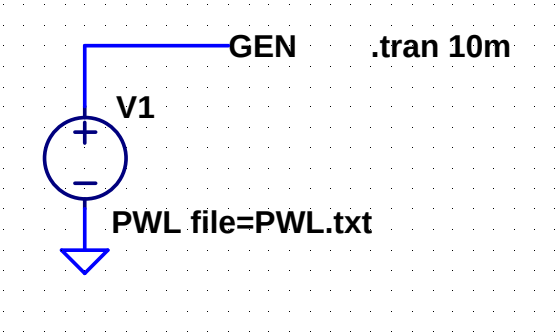


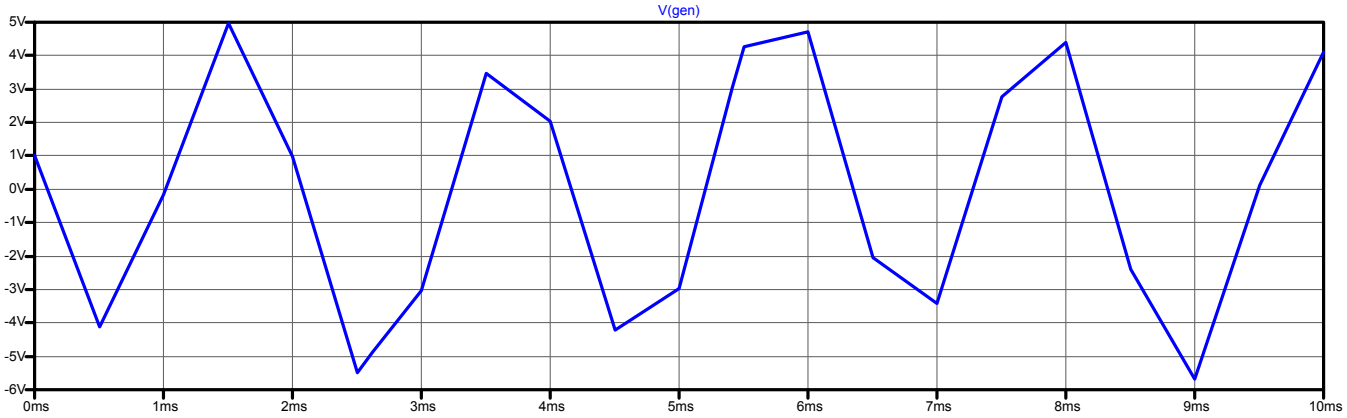
PWL – Esempio 1





PWL – Esempio 2





PWL – Esempio 2

PWL.txt

```
  0.00e+00    1.00e+00
  5.00e-04   -4.11e+00
  1.00e-03   -1.65e-01
  1.50e-03    4.96e+00
  2.00e-03    9.81e-01
  2.50e-03   -5.49e+00
  3.00e-03   -3.05e+00
  3.50e-03    3.46e+00
  4.00e-03    2.03e+00
  4.50e-03   -4.23e+00
  5.00e-03   -2.97e+00
  5.50e-03    4.27e+00
  6.00e-03    4.72e+00
  6.50e-03   -2.05e+00
  7.00e-03   -3.43e+00
  7.50e-03    2.78e+00
  8.00e-03    4.38e+00
  8.50e-03   -2.40e+00
  9.00e-03   -5.69e+00
  9.50e-03    1.22e-01
  1.00e-02    4.10e+00
```