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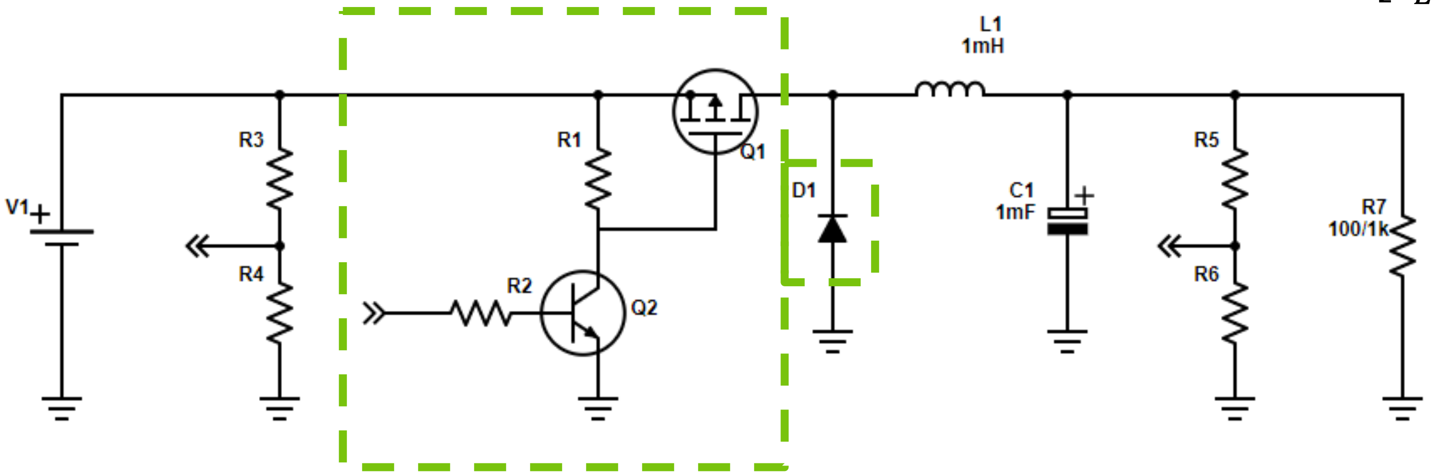
Controlli Automatici A.A. 2018/2019

Buck Converter

Circuito e modellizzazione

$$x = \begin{bmatrix} V_C \\ I_L \end{bmatrix}$$



$$\dot{x} = \begin{bmatrix} -\frac{1}{RC} & \frac{1}{C} \\ -\frac{1}{L} & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ \frac{E}{L} \end{bmatrix} d$$

$$y = \begin{bmatrix} 1 & 0 \end{bmatrix} x$$

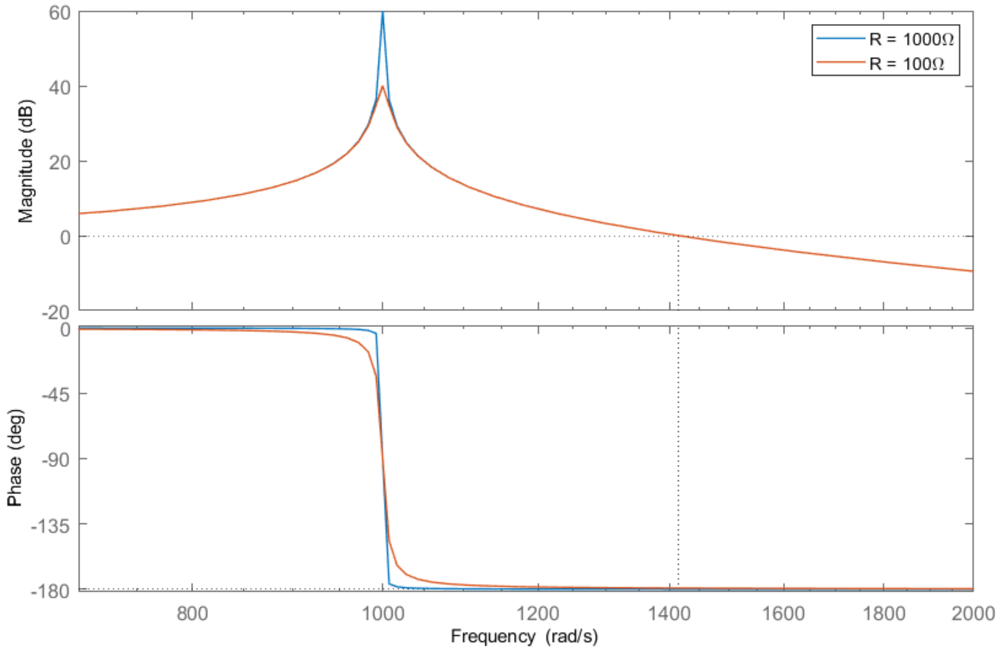
R=100Ω

$$\dot{x} = \begin{bmatrix} -100 & 1000 \\ -1000 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1000 \end{bmatrix} d * E$$

$$y = \begin{bmatrix} 1 & 0 \end{bmatrix} x$$

Buck Converter

Funzione di Trasferimento



R=100Ω → $G(s) = \dfrac{1}{\dfrac{s^2}{10^6} + \dfrac{s}{10^5} + 1}$

R=1000Ω → $G(s) = \dfrac{1}{\dfrac{s^2}{10^6} + \dfrac{s}{10^6} + 1}$

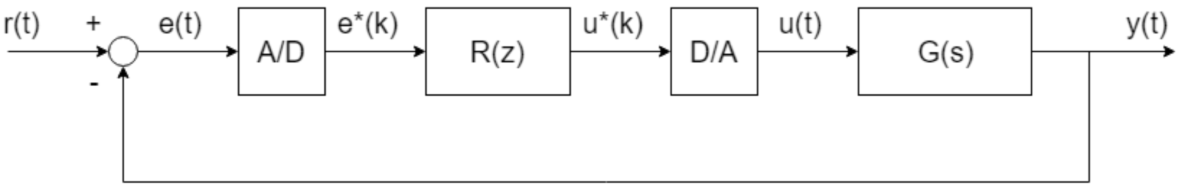
$$\omega_n = \frac{1}{\sqrt{LC}}$$

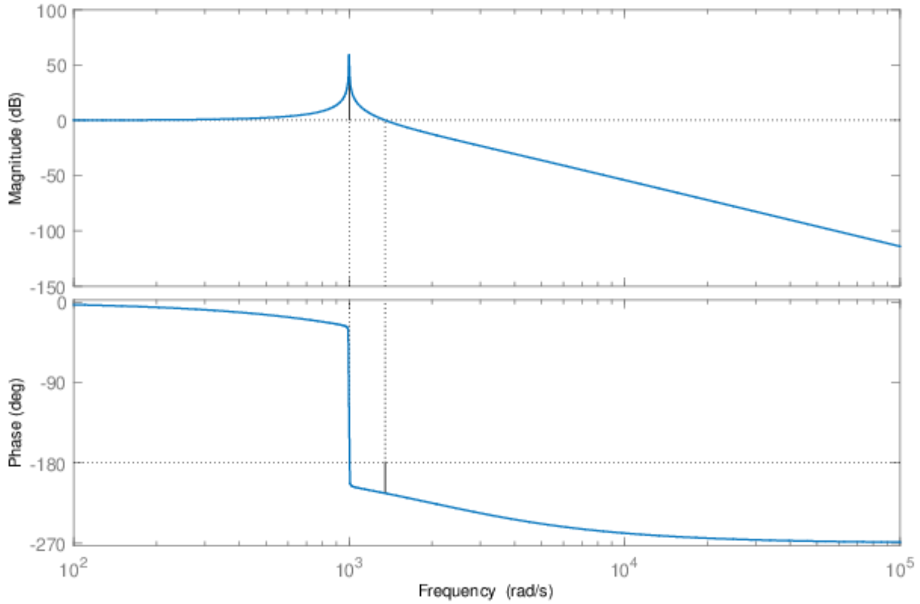
$$\zeta = \frac{1}{2R}\sqrt{\frac{L}{C}}$$

Controllo Digitale

Volendo realizzare un controllo digitale bisogna considerare un polo alla pulsazione :

$$\frac{2}{T_C}$$

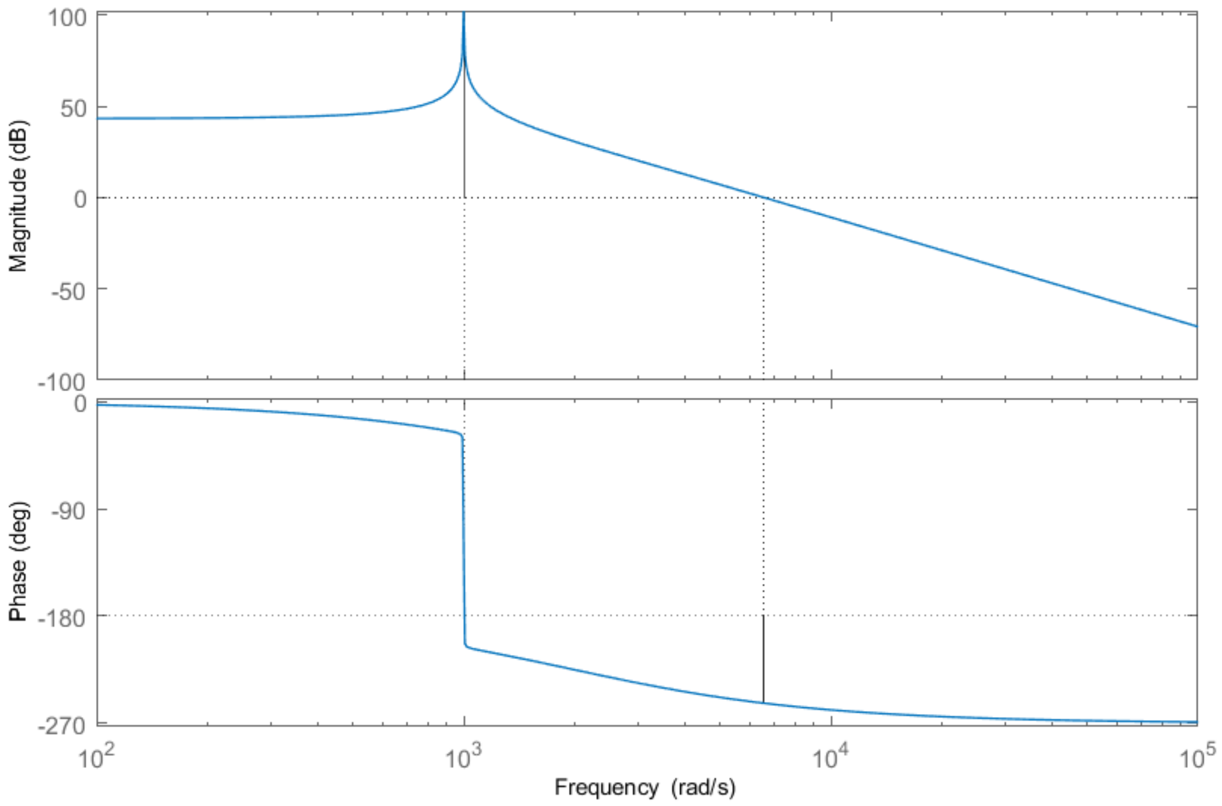




$$G^*(s) = \frac{1}{1 + \frac{T_C}{2}s} * \frac{1}{\frac{s^2}{10^6} + \frac{s}{10^6} + 1}$$

Loop Shaping

Definizione delle Specifiche

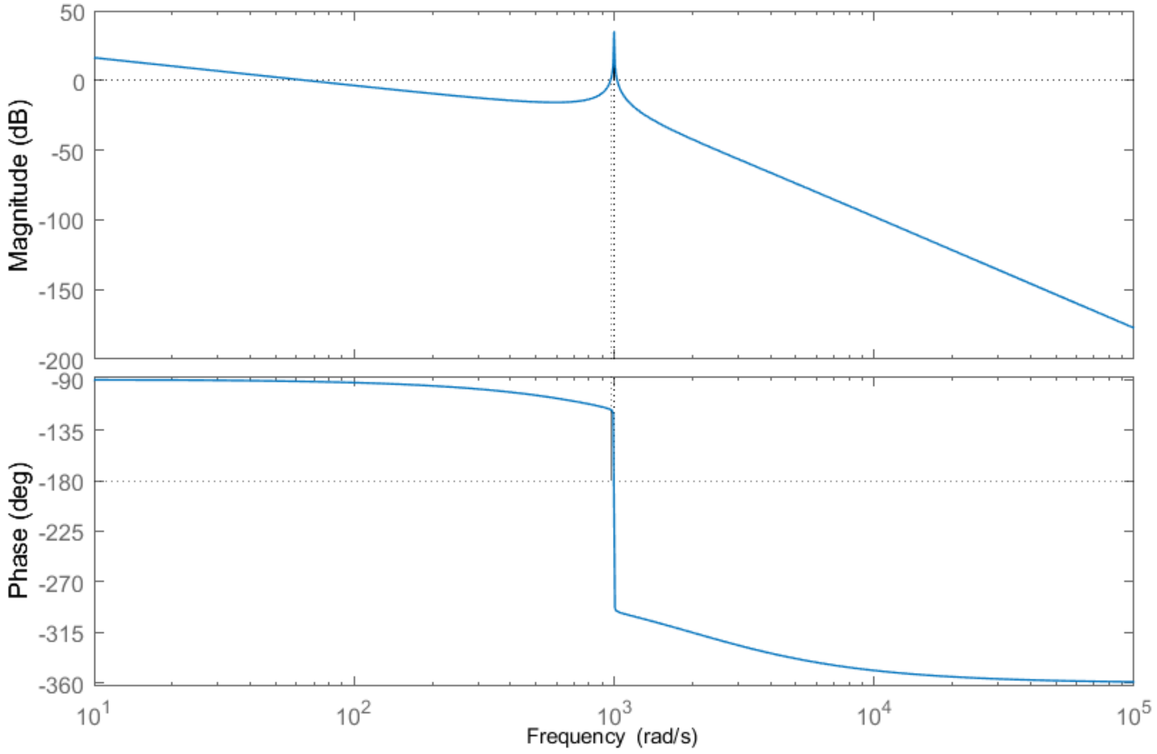


$$T_{a5} = 1ms \longrightarrow \omega_C = -\frac{\ln(0.01 * 5)}{T_{a5} * \zeta} \approx 6571\, rad/s$$

$$S_{\%} = 20\% \longrightarrow \emptyset_m \approx 54.25° + 10° = 64.25°$$

$$f_C = \frac{100}{T_{a5}} = 100kHz$$

Definizione delle Specifiche



$$f_C = \frac{100}{T_{a5}} = 1kHz$$

$$T_{a5} = 100ms$$

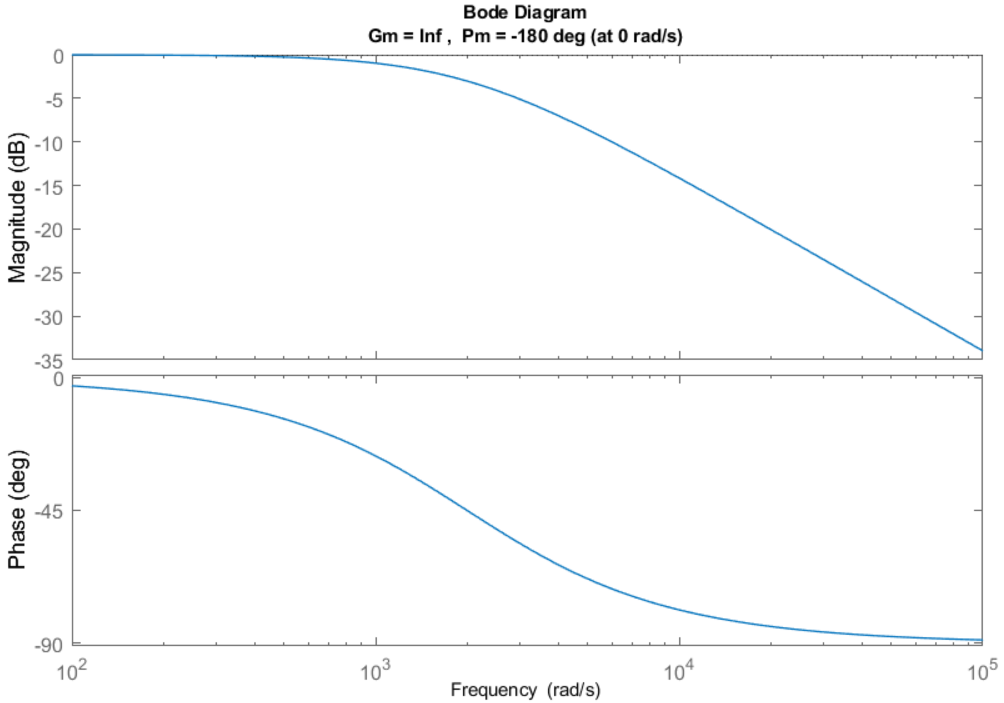
$$\omega_C = -\frac{\ln(0.01 * 5)}{T_{a5} * \zeta} \approx 65.71\, rad/s$$

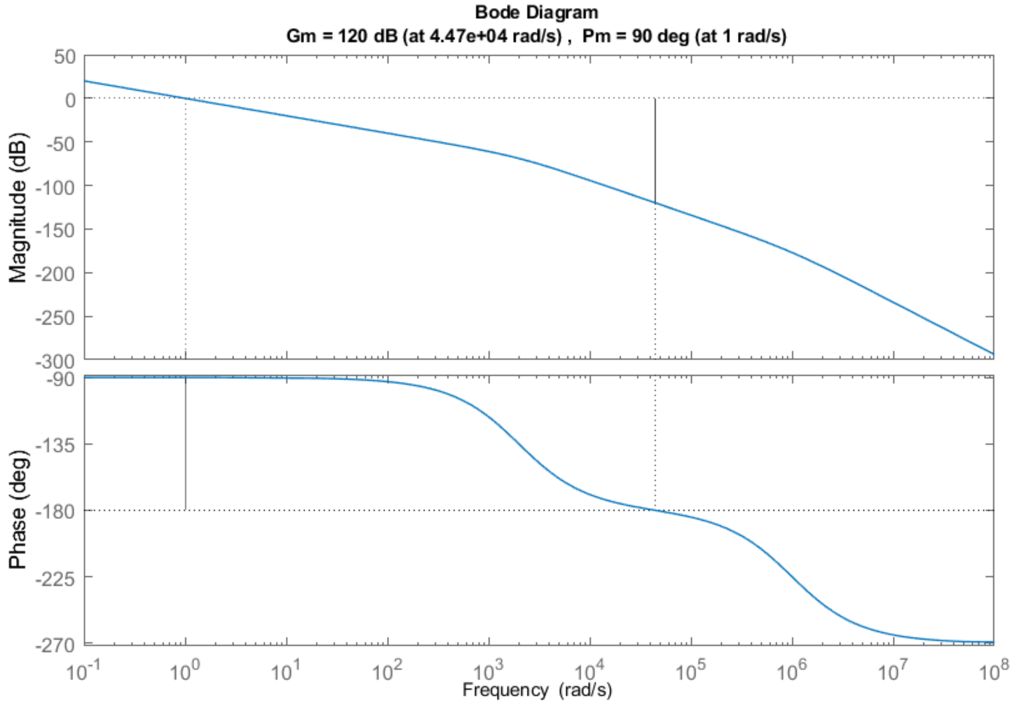
$$R(s) = \frac{k}{s}$$

Progettazione del Regolatore – Loop Shaping

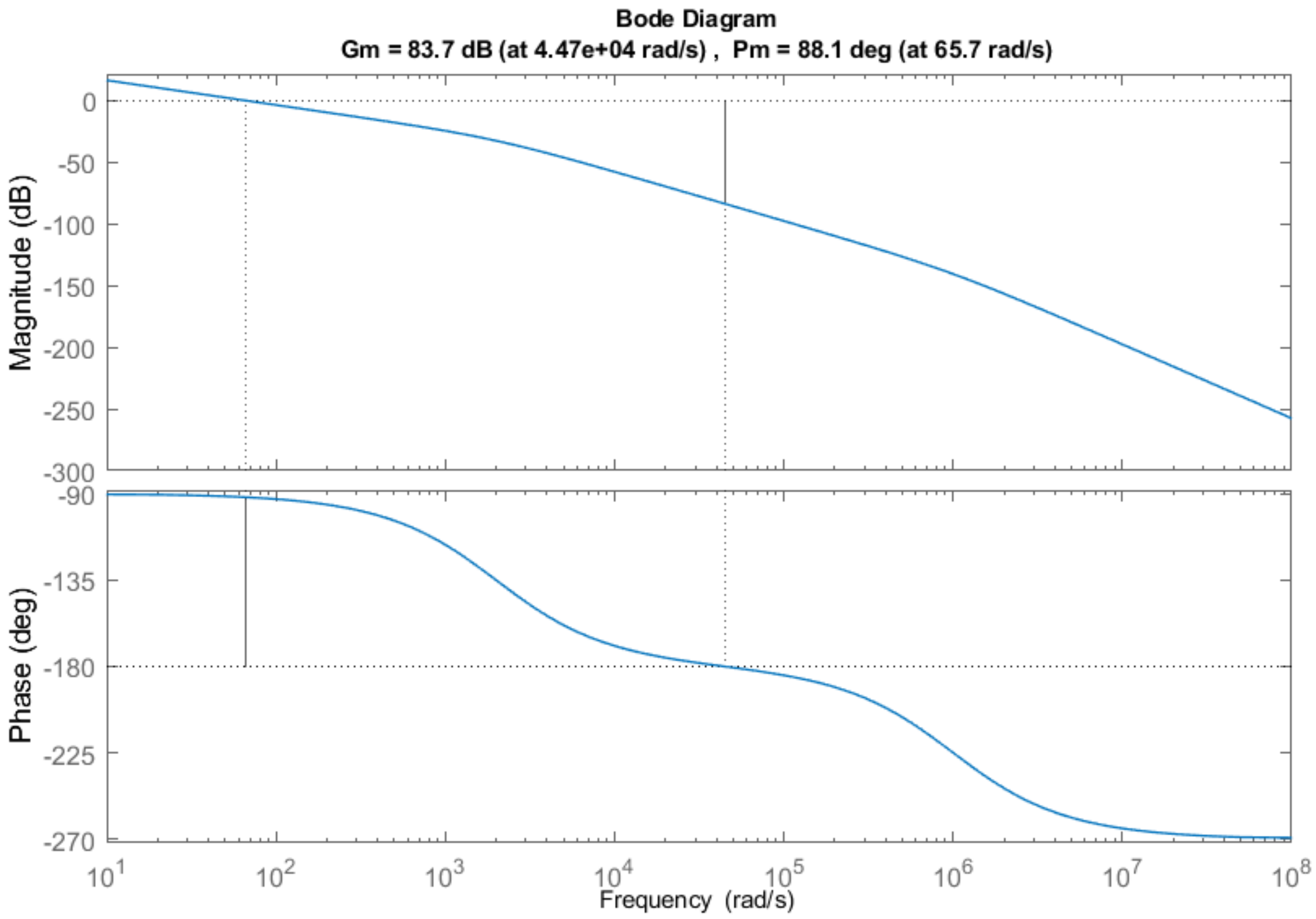
$$R(s) = \frac{s^2}{10^6} + \frac{s}{10^6} + 1$$

$$R(s) = \frac{\frac{s^2}{10^6} + \frac{s}{10^6} + 1}{s\left(\frac{s}{10^6} + 1\right)}$$



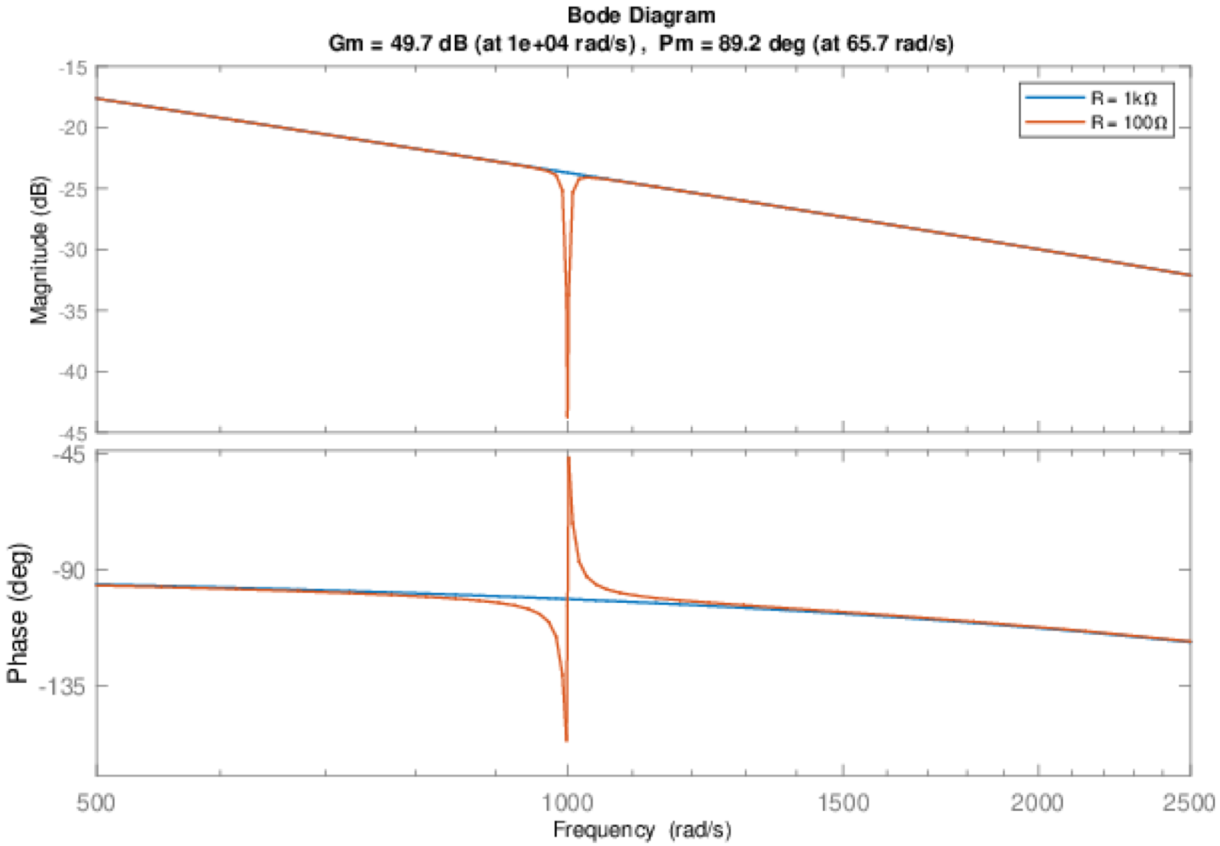


Progettazione del Regolatore – Loop Shaping

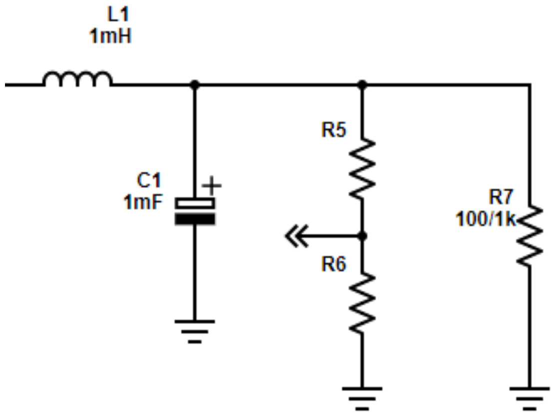


$$R(s) = 65.7895 * \frac{\frac{s^2}{10^6} + \frac{s}{10^6} + 1}{s\left(\frac{s}{10^6} + 1\right)}$$

Considerazioni – Loop Shaping



$$R = 100 \div 1000\Omega$$



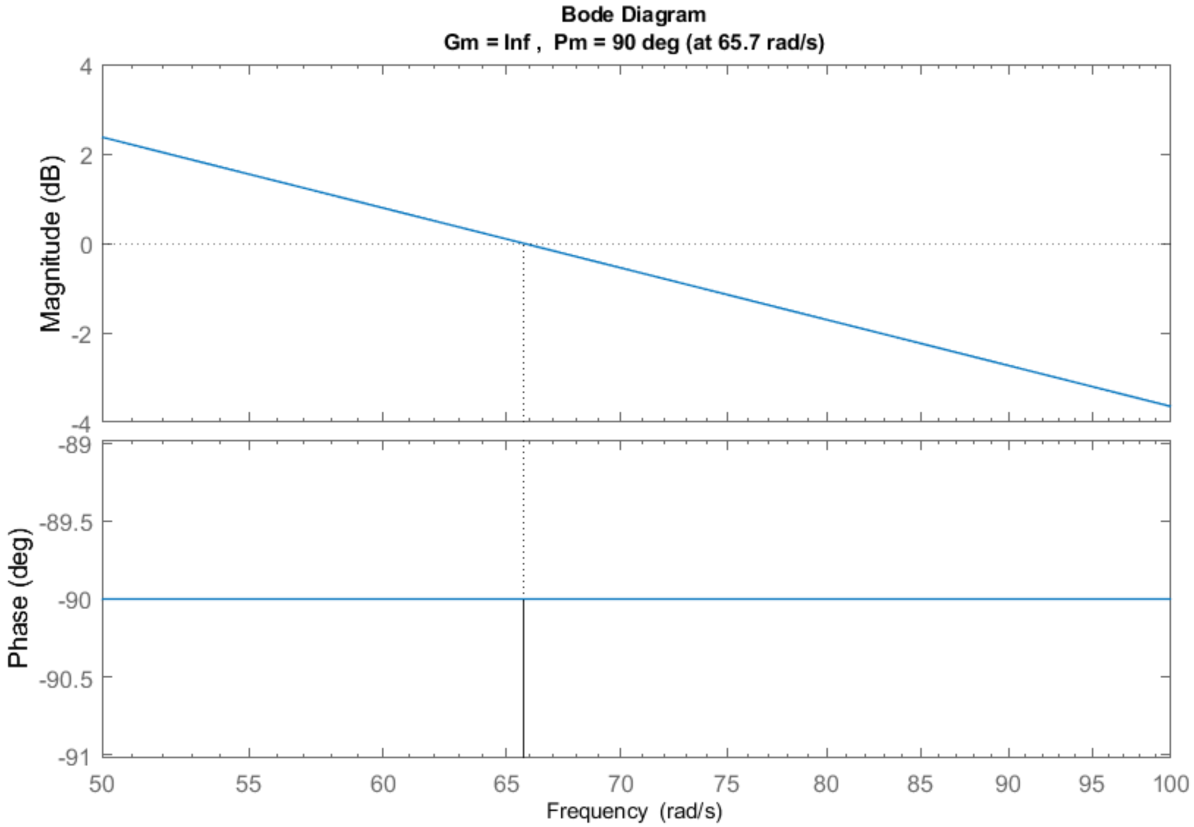
Sintesi per Cancellazione

Specifiche - Cancellazione

$T_{a5} = 100ms$ → $\omega_C \approx 65.7\ rad/s$

$S_{\%} = 20\%$ → $\emptyset_m \approx 64.25°$

$$L(s) = \frac{65.7895}{s}$$



Progettazione del Regolatore - Cancellazione

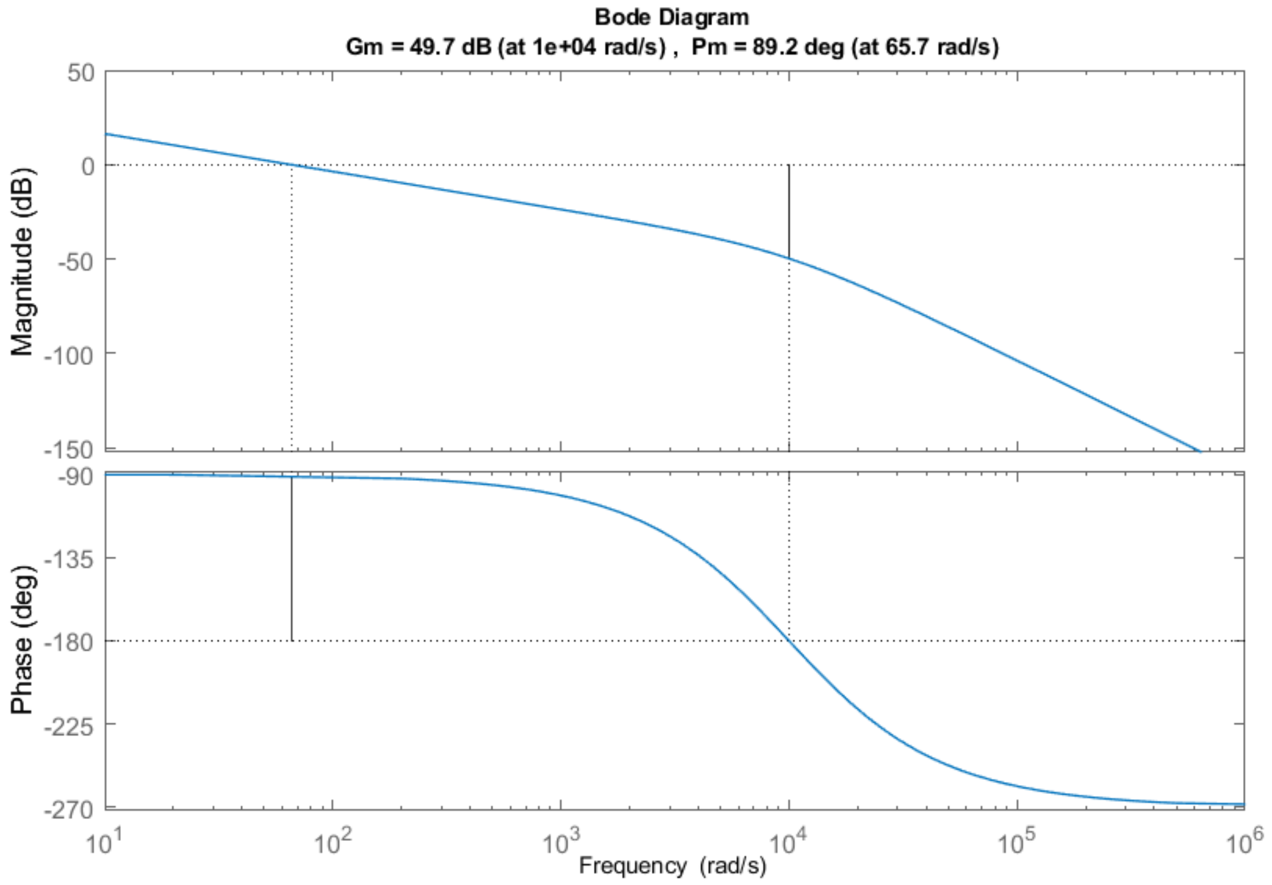
$$L(s) = R(s) * G^*(s)$$

↓

$$R(s) = \frac{L(s)}{G^*(s)} = \frac{65.7895\left(1+\frac{T_C}{2}s\right)\left(\frac{s^2}{10^6}+\frac{s}{10^6}+1\right)}{s}$$

↓

$$R(s) = \frac{L(s)}{G^*(s)} = \frac{65.7895\left(1+\frac{T_C}{2}s\right)\left(\frac{s^2}{10^6}+\frac{s}{10^6}+1\right)}{s\left(1+\frac{s}{10^4}\right)^2}$$



Discretizzazione

Discretizzazione

- Metodo bilineare (o di Tustin) → $$R(z) = R(s)\big|_{s=\frac{2}{T_C}\frac{(z-1)}{(z+1)}}$$
- Metodo dell'invarianza della risposta all'impulso → $$R(z) = \frac{z-1}{z} Z\left\{ L^{-1}\left\{ R(s)\frac{1}{s} \right\}\Big|_{t=kT_C} \right\}$$

$$R(z) = \frac{0.1641z^2 - 0.1968z + 0.164}{z^2 - 0.003992z + 0.996}$$

Loop Shaping - Tustin

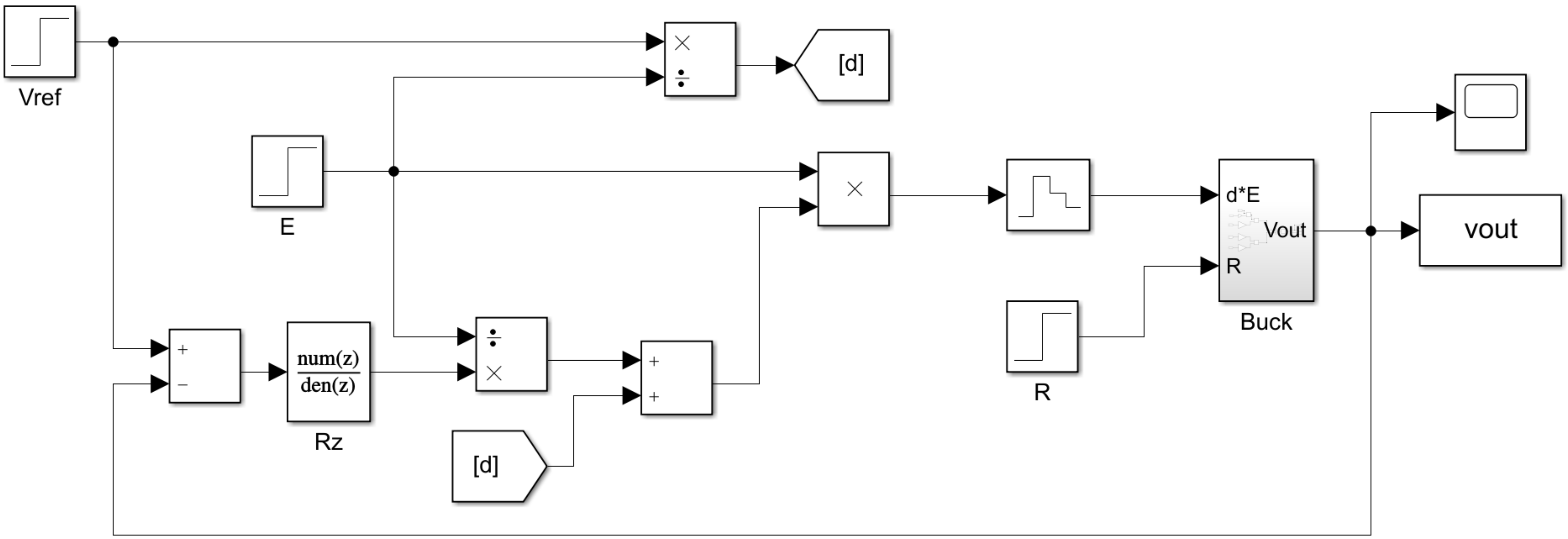
$$R(z) = \frac{0.2283z^3 - 0.2738z^2 + 0.2281z + 2.884 * 10^{-16}}{z^3 + 0.3333z^2 - 0.8889z - 0.4444}$$

Cancellazione - Tustin

```
R = tf(c2d(SYSC,TS,METHOD));
```

Simulazioni e Prove Sperimentali

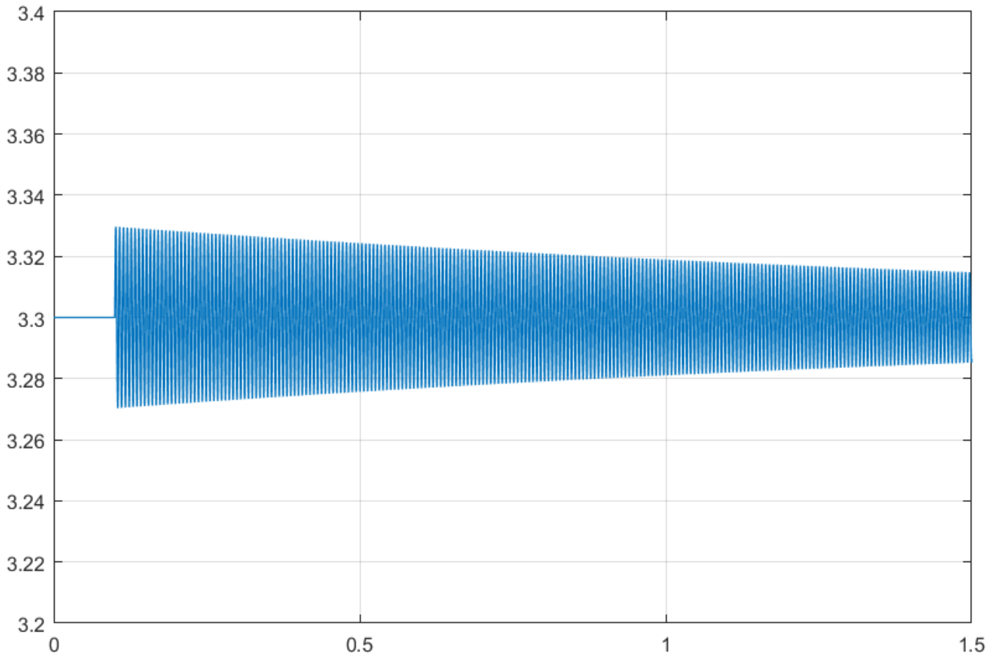
Schema di controllo



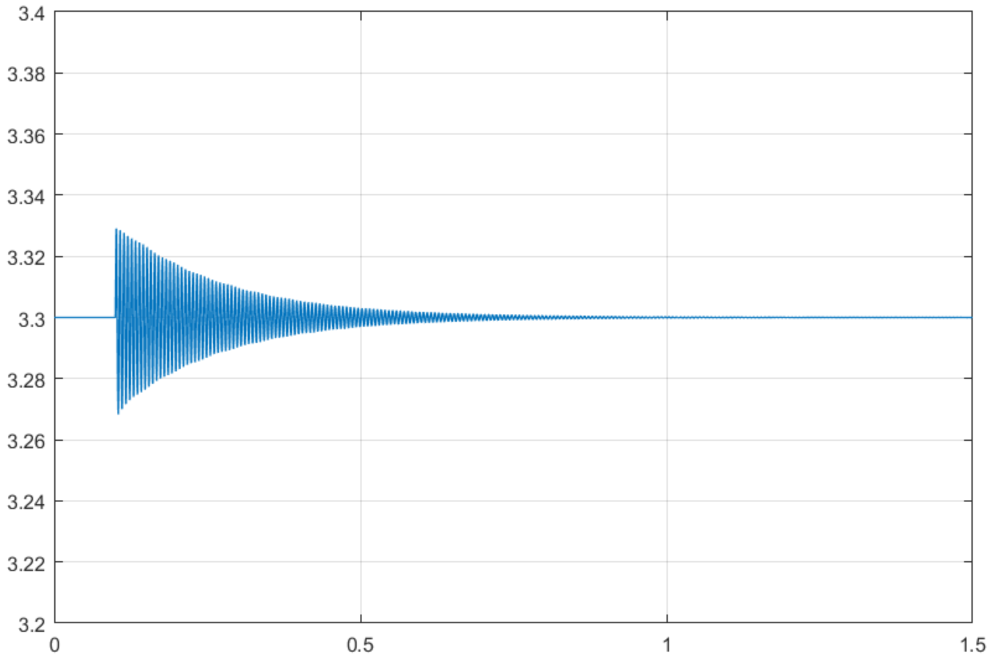
$t = 0.1s$ → $R = 100\Omega \rightarrow R = 1000\Omega$

$t = 0.6s$ → $E = 6V \rightarrow E = 8V$

Simulazione – Loop Shaping

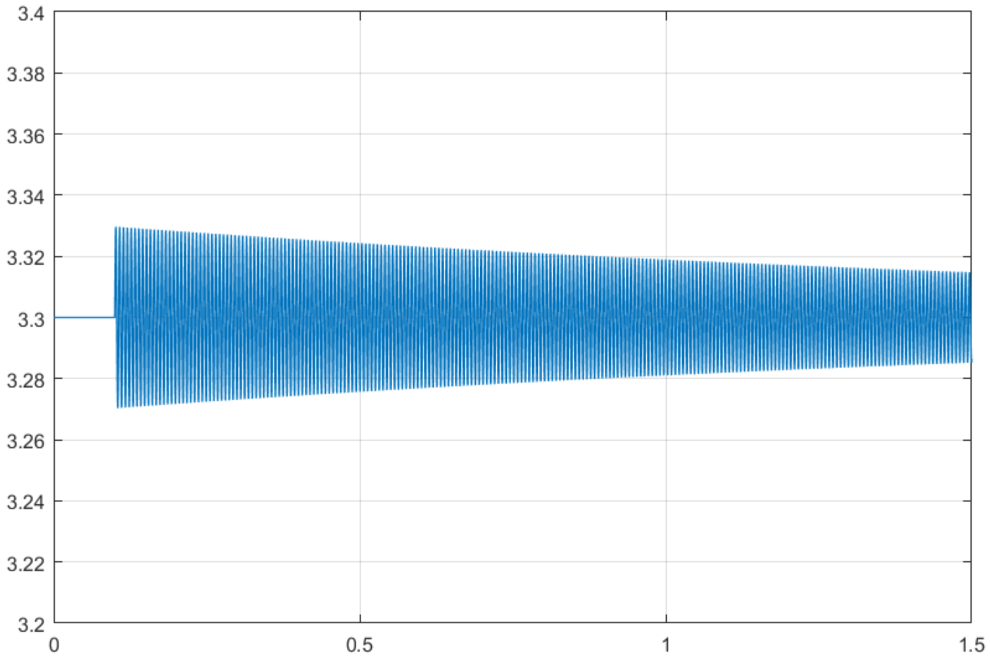


Risposta del sistema ad
anello aperto

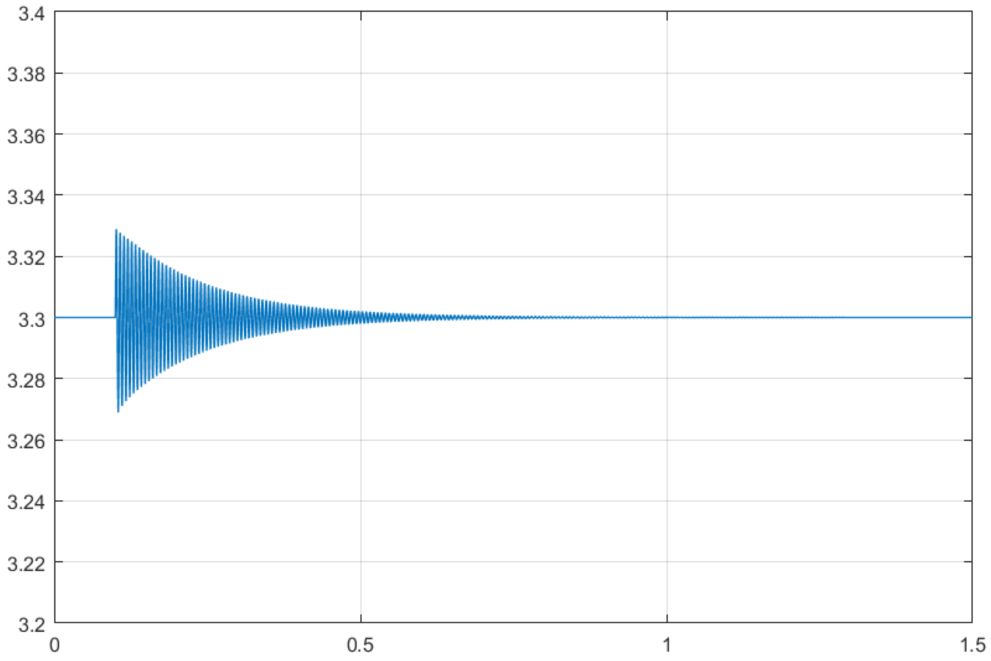


Risposta del sistema ad
anello chiuso

Simulazione – Cancellazione

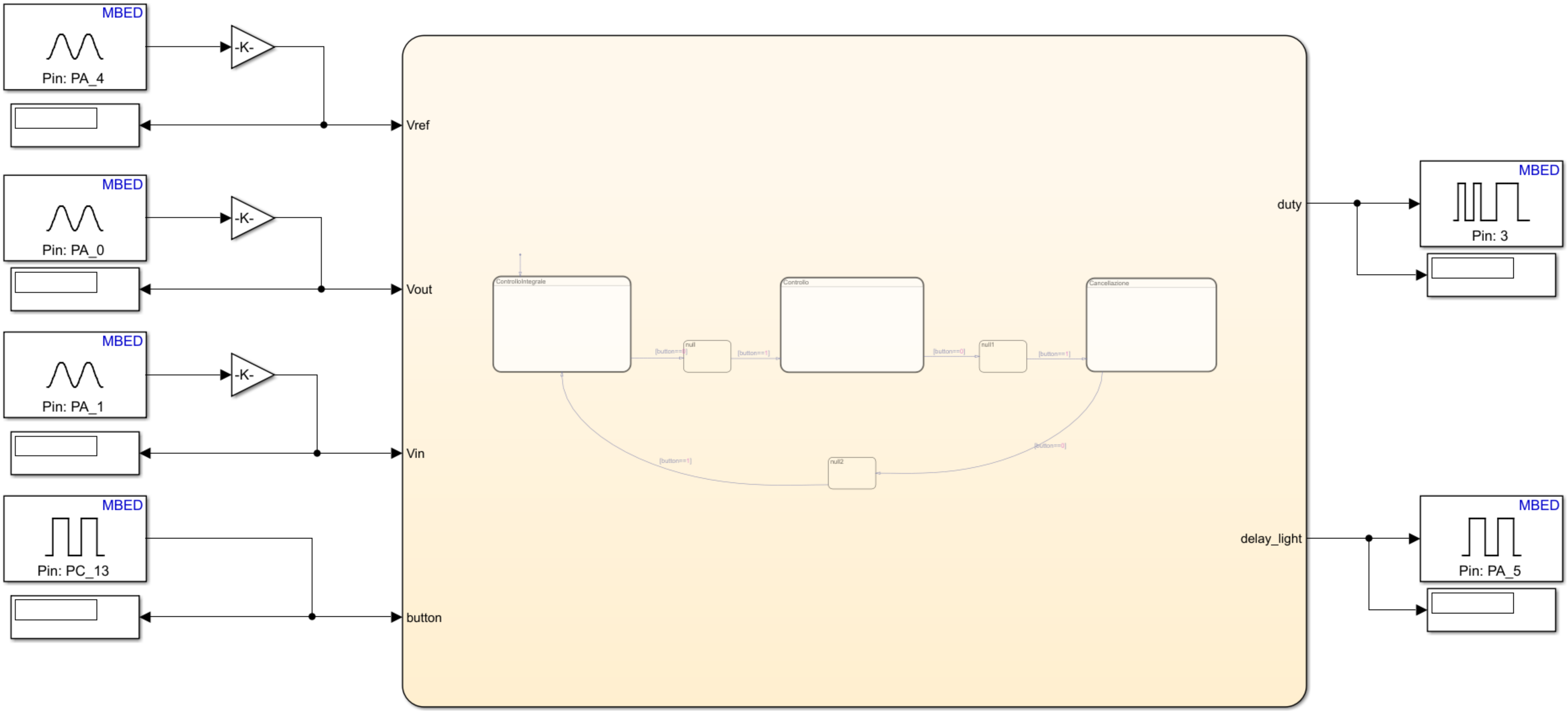


Risposta del sistema ad
anello aperto



Risposta del sistema ad
anello chiuso

Implementazione - Simulink



Prove Sperimentali

$R = 100\Omega \rightarrow R = 1000\Omega$

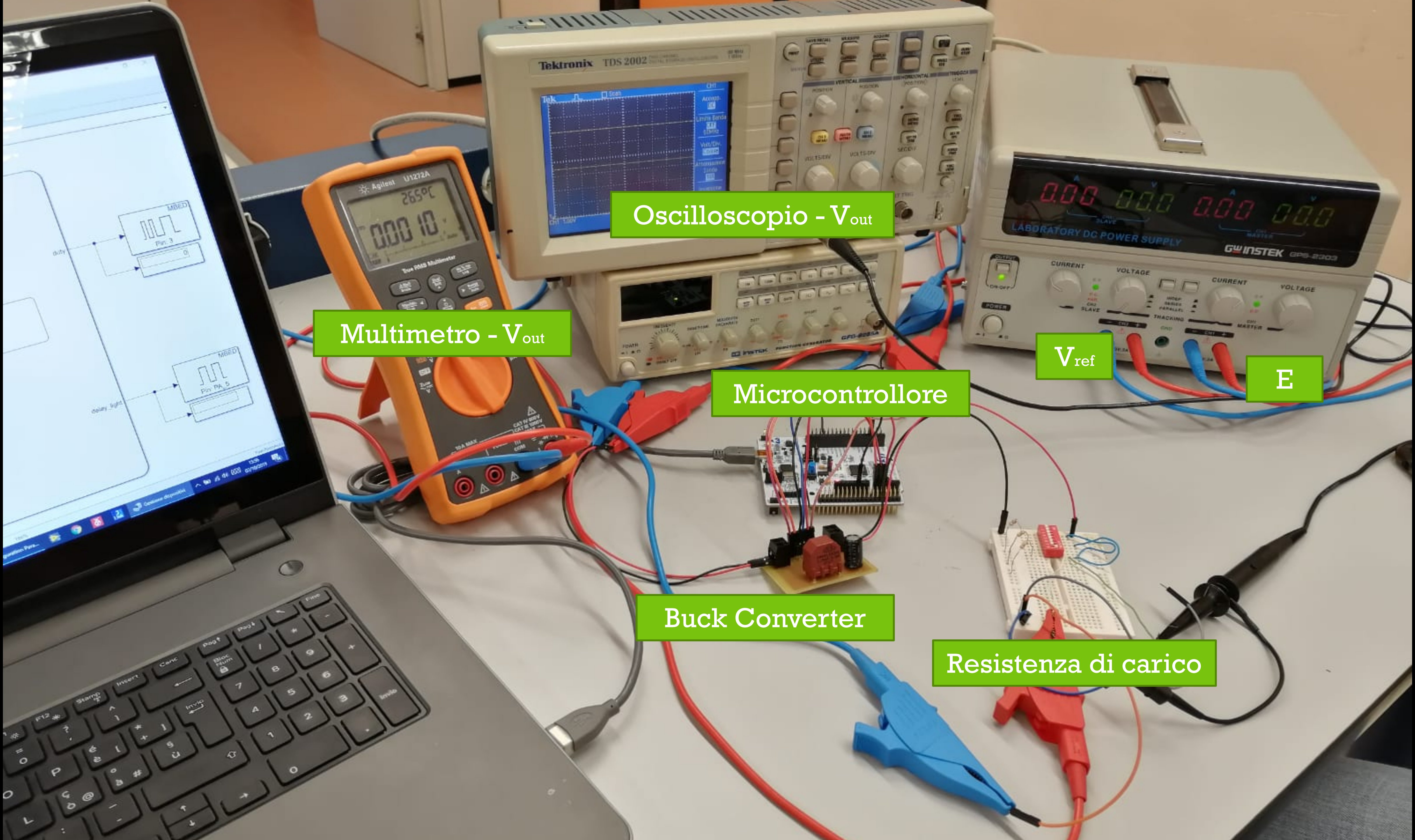
$V_{ref} = 5V$

$E = 10V$

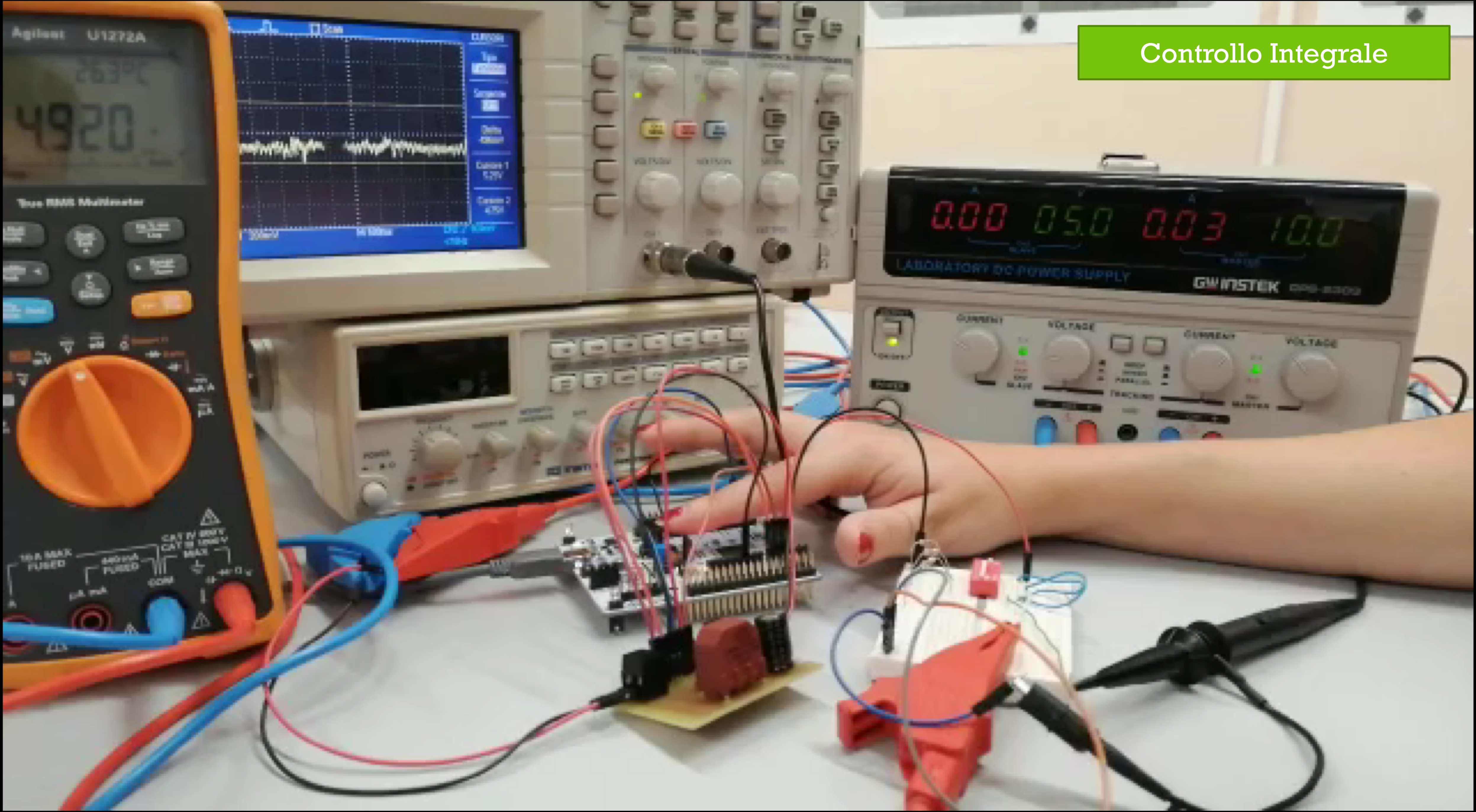
Controllo	T_{a5}(ms)	$S_{\%}$(%)
Integrale	390	28.4
Loop Shaping	600	16.4
Cancellazione	600	18

$E = 8V$

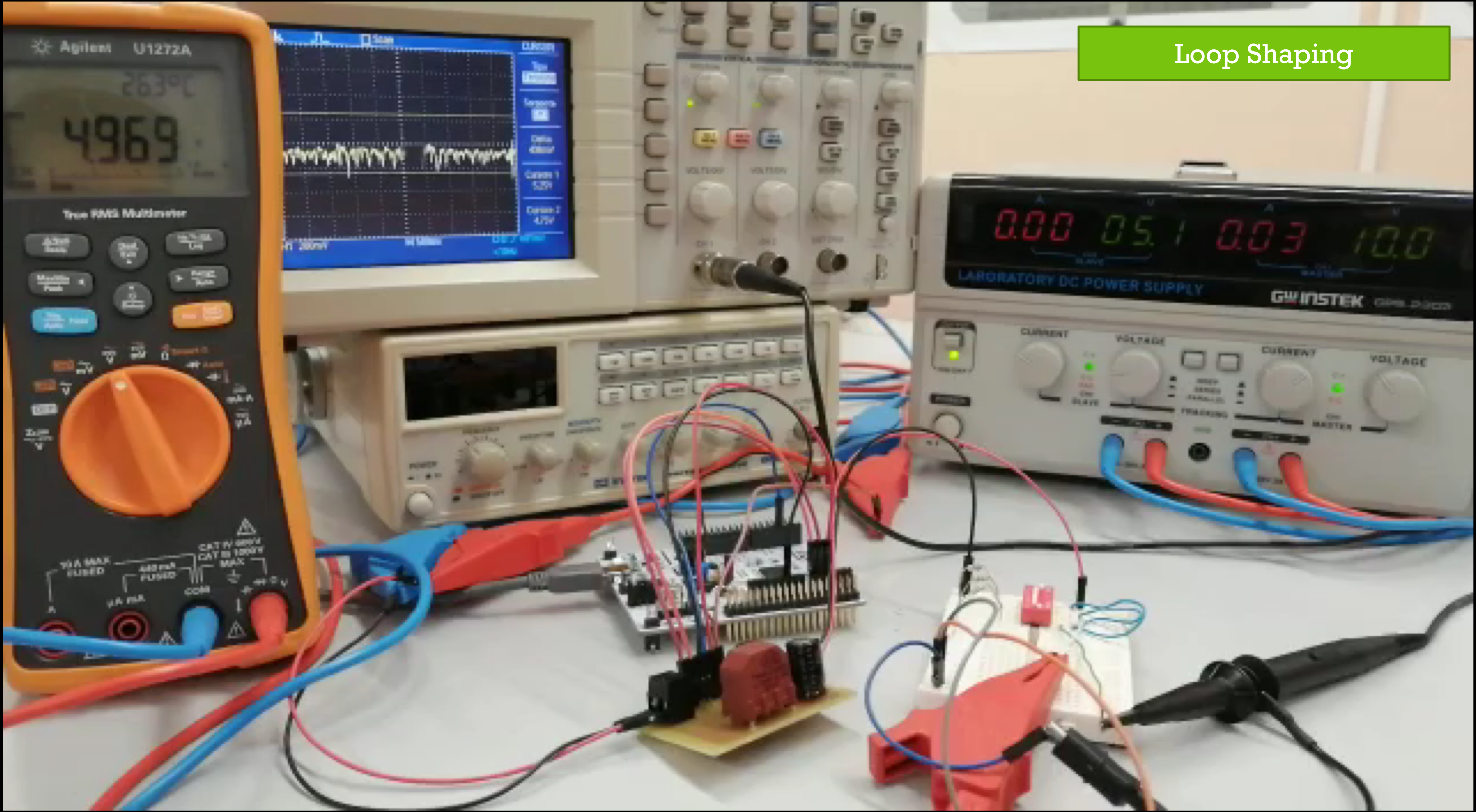
Controllo	T_{a5}(ms)	$S_{\%}$(%)
Integrale	640	20.4
Loop Shaping	360	11.6
Cancellazione	450	14.4


Oscilloscopio - V_{out}
Multimetro - V_{out}
Microcontrollore
V_{ref}
E
Buck Converter
Resistenza di carico
Tektronix TDS 2002
Agilent U1272A
LABORATORY DC POWER SUPPLY
GW INSTEK GPS-2303

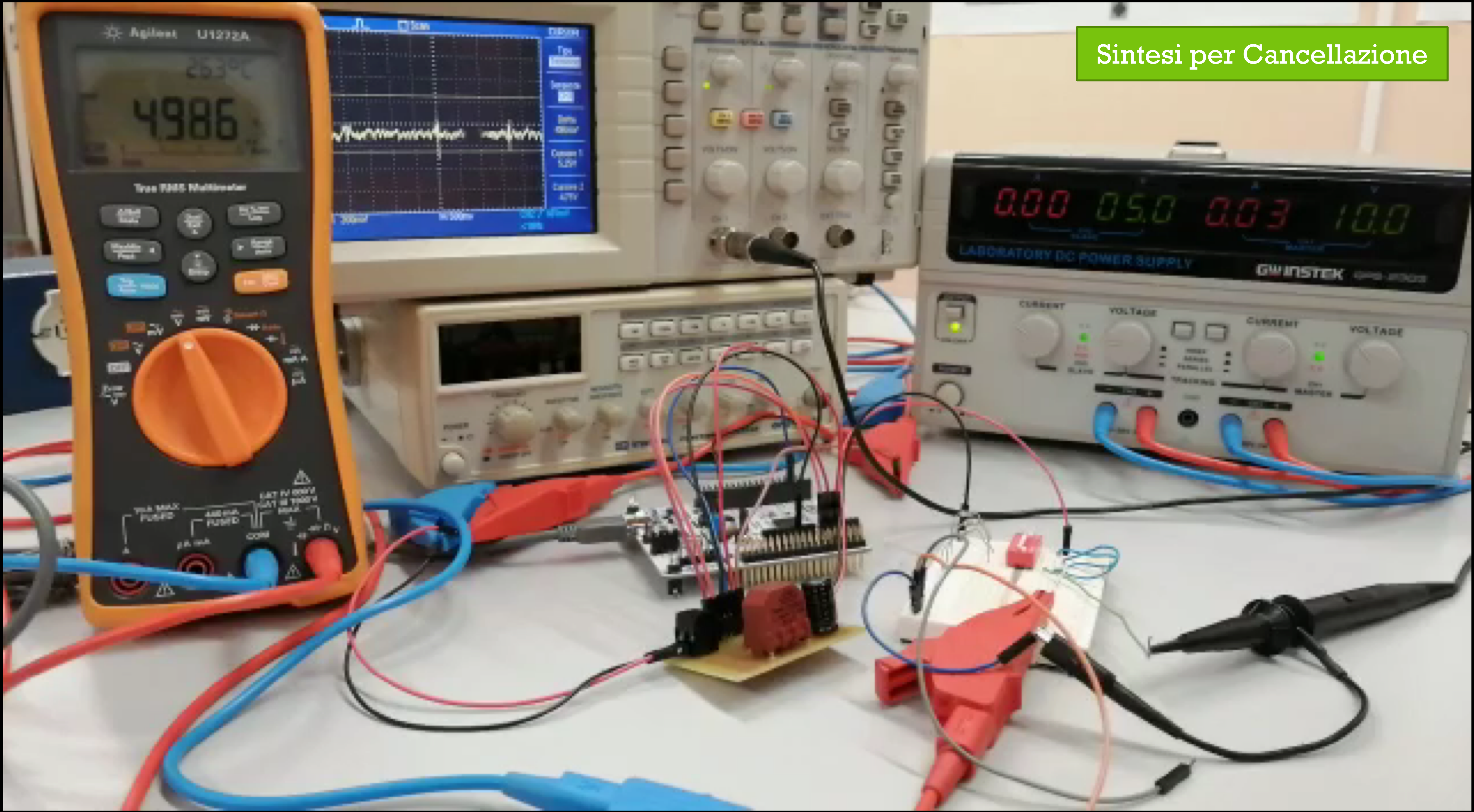
Controllo Integrale



Loop Shaping



Sintesi per Cancellazione



Variazione V_{ref}