**Control & Identification Toolbox**

# Control & Identification Toolbox

Input ⟶ System ⟶ Output

Perturbations

Reference $+$ ⊕ $-$ $e(t)$ → Control $u(t)$ → ⊕ → Plant → Output

Excitation
$u(t) = u_1(t) + u_2(t) + u_3(t)$

Plant
$G(s) \; = \; \frac{\alpha_1 s + \alpha_2}{s + \alpha_3}$

Output
$y(t)$

Least Squares identification method

$$\widehat{\boldsymbol{\theta}}(k) = \widehat{\boldsymbol{\theta}}(k-1) + L(k)\epsilon(k)$$

$$L(k) = \frac{\boldsymbol{P}(k-1)\phi(k)}{\gamma + \phi^T(k)\boldsymbol{P}(k-1)\phi(k)}$$

$$\boldsymbol{P}(k) = \frac{1}{\gamma}\left[\boldsymbol{P}(k-1) - \frac{\boldsymbol{P}(k-1)\phi(k)\phi(k)^T\boldsymbol{P}(k-1)}{\gamma + \phi^T(k)\boldsymbol{P}(k-1)\phi(k)}\right]$$

$$\epsilon(k) = y(k) - \widehat{y}(k)$$

$$\widehat{y}(k) = \phi^T(k)\widehat{\boldsymbol{\theta}}(k-1)$$

Estimates
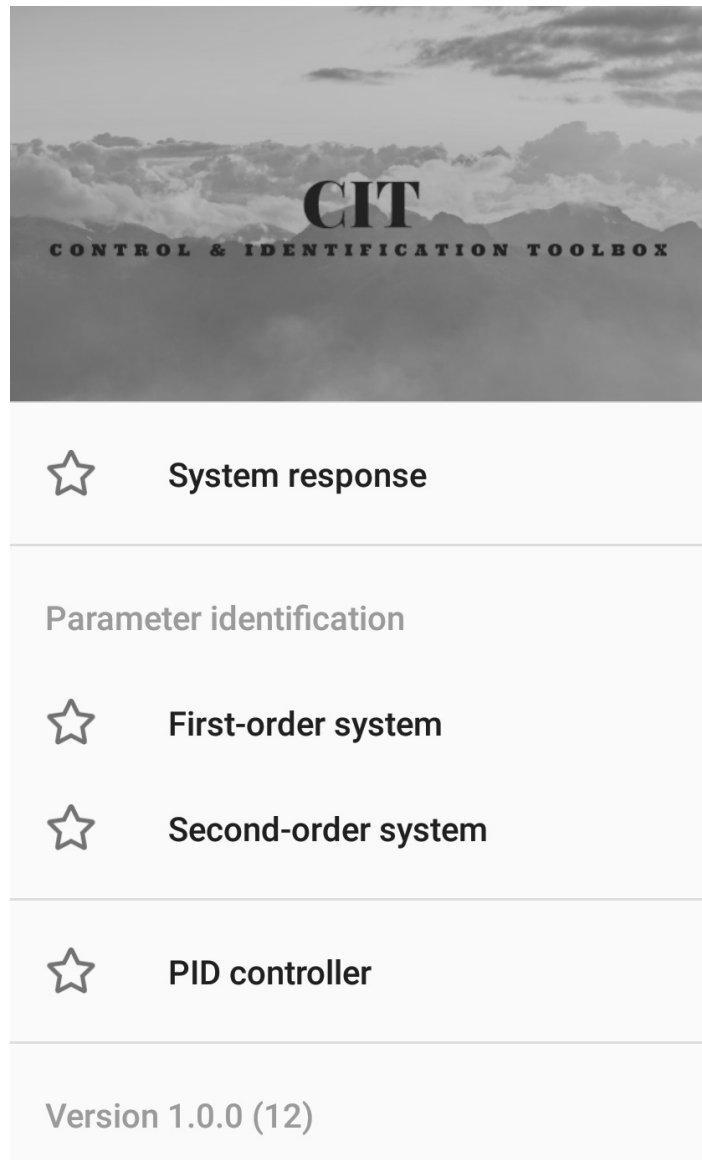$\hat{\theta}(k)$

Figure 1: Home-screen of the CIT android application

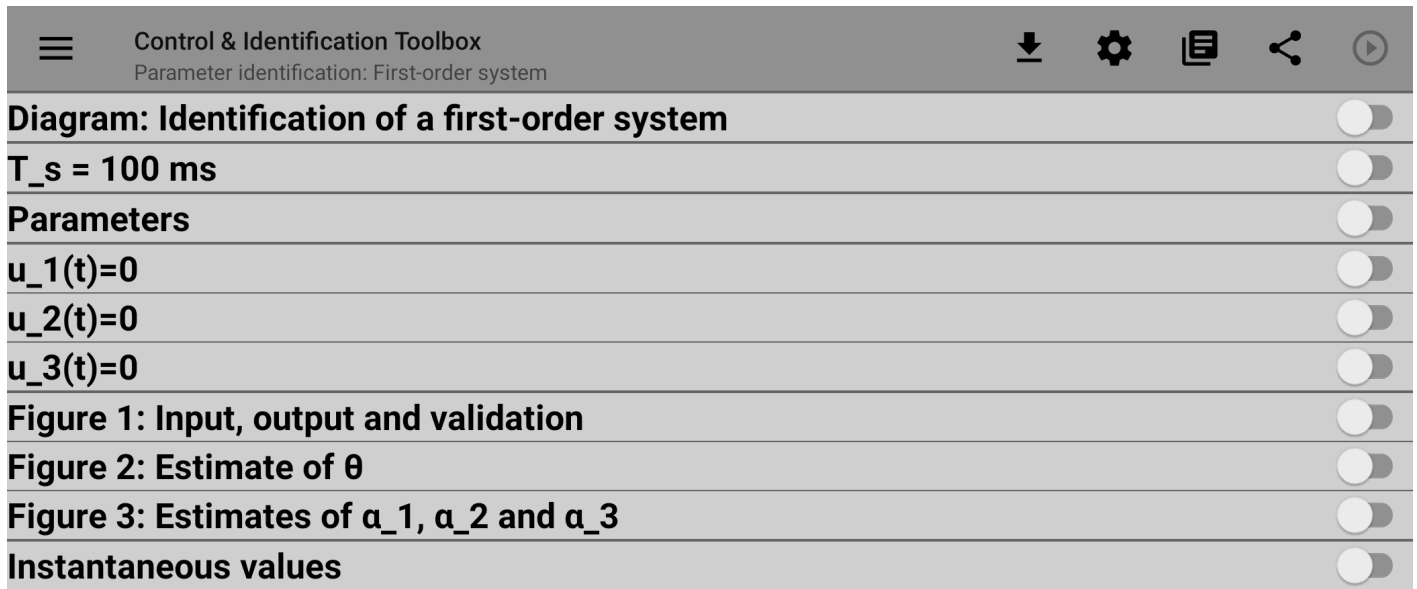Figure 2: Drawer of the CIT android application

**Control & Identification Toolbox**
Parameter identification: First-order system

**Diagram: Identification of a first-order system**

**T_s = 100 ms**

**Parameters**

**u_1(t)=0**

**u_2(t)=0**

**u_3(t)=0**

**Figure 1: Input, output and validation**

**Figure 2: Estimate of θ**

**Figure 3: Estimates of α_1, α_2 and α_3**

**Instantaneous values**

Figure 3: Experimental results screen (ERS) for first-order parameter identification

```
 1: Initialize USB CDC to the boudrate = 115 200 bit s⁻¹
 2: while 1 do
 3:     Receive from USB and store in A
 4:     if A[0] == 0x34 then
 5:         Set the value of A[2] as PWM out to the Analog
        output port # A[1]− 0x60
 6:     end if
 7:     if A[0] == 0x33 then
 8:         Read analog value from the Analog input # A[1]−
        0x60 and send the value to USB
 9:     end if
10: end while
```

Figure 4: Bridge device's firmware
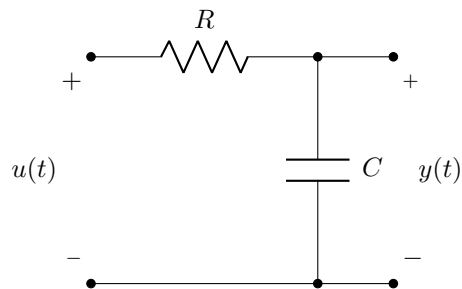
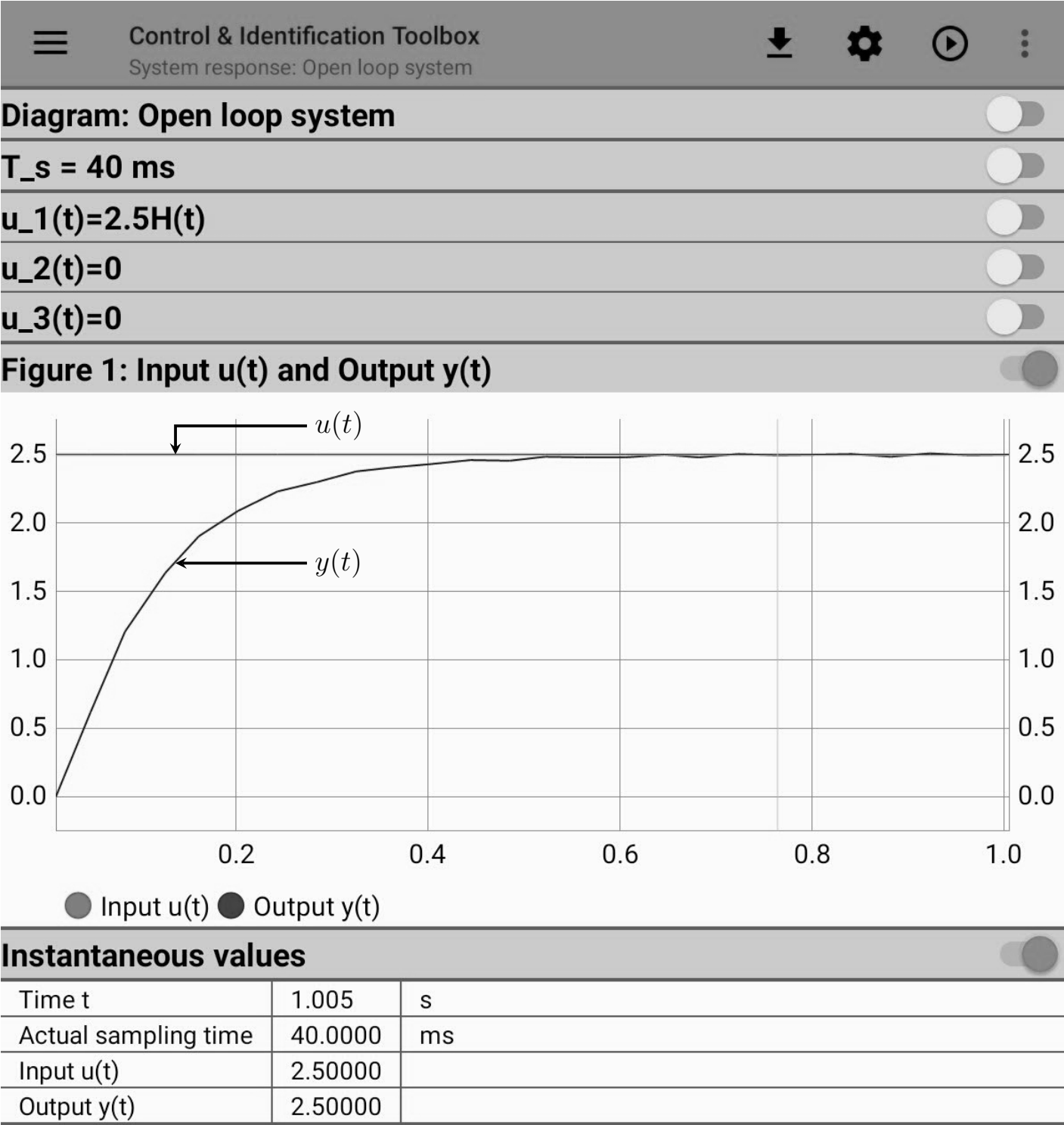Figure 5: First order low pass filter
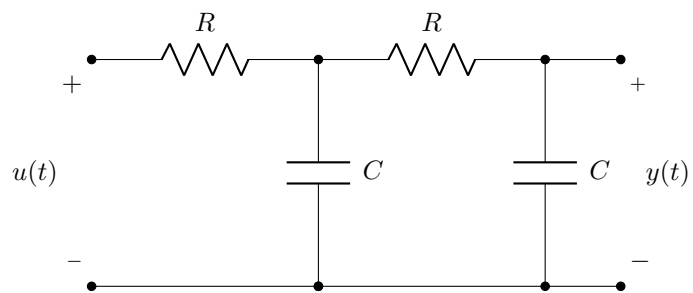
Figure 6: Second order low pass filter.
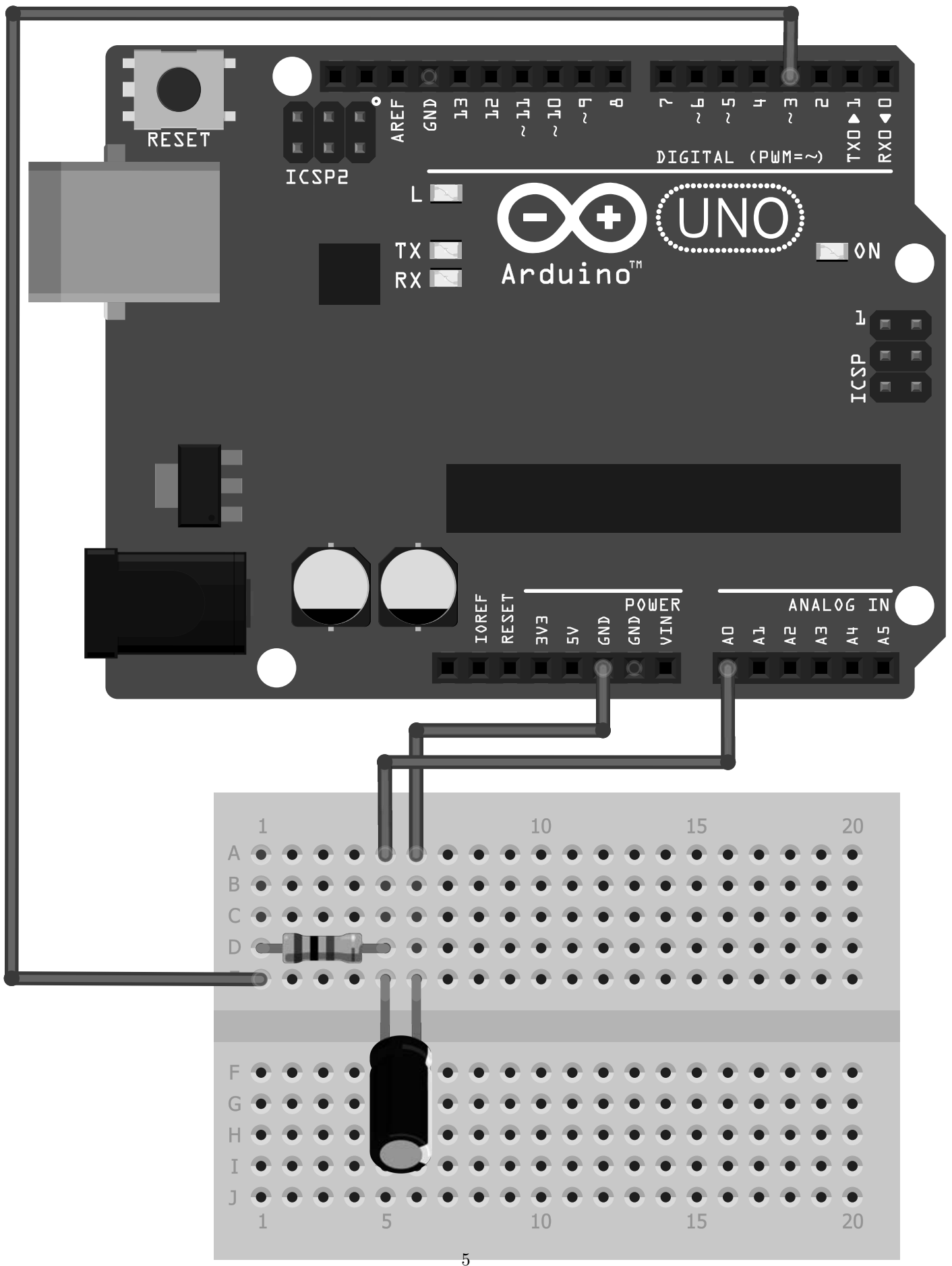
Figure 7: Bridge circuit with a first order RC low pass filter

**Diagram: Open loop system**

**T_s = 40 ms**

**u_1(t)=2.5H(t)**

**u_2(t)=0**

**u_3(t)=0**

**Figure 1: Input u(t) and Output y(t)**



● Input u(t) ● Output y(t)

**Instantaneous values**

| Time t | 1.005 | s |
|---|---|---|
| Actual sampling time | 40.0000 | ms |
| Input u(t) | 2.50000 | |
| Output y(t) | 2.50000 | |

Figure 8: Step response of the first-order low pass filter.
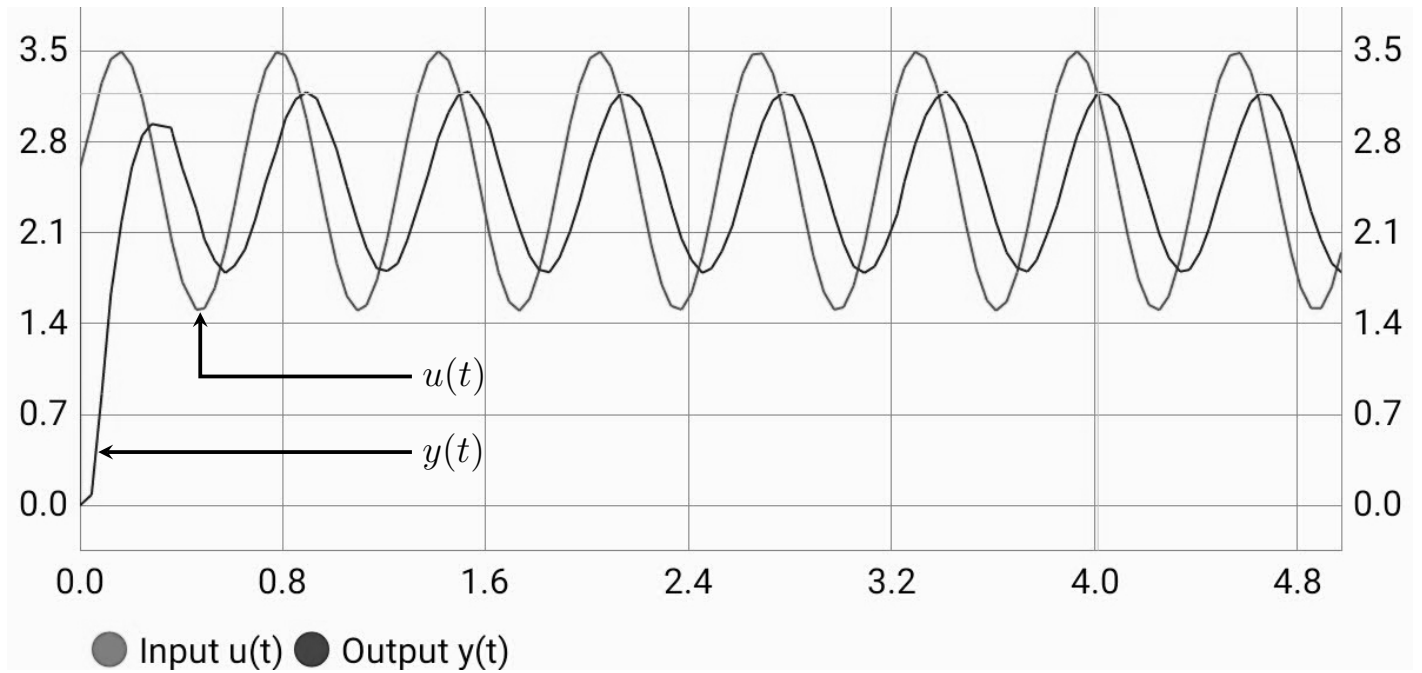
Figure 9: Sinusoidal response of the fist-order low pass filter.
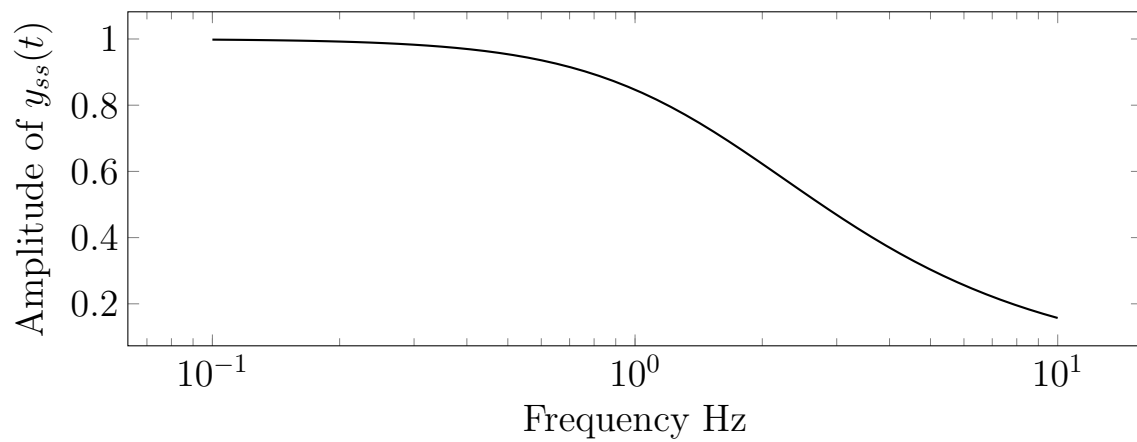


Figure 10: Magnitude of the frequency response of the first-order low pass filter.
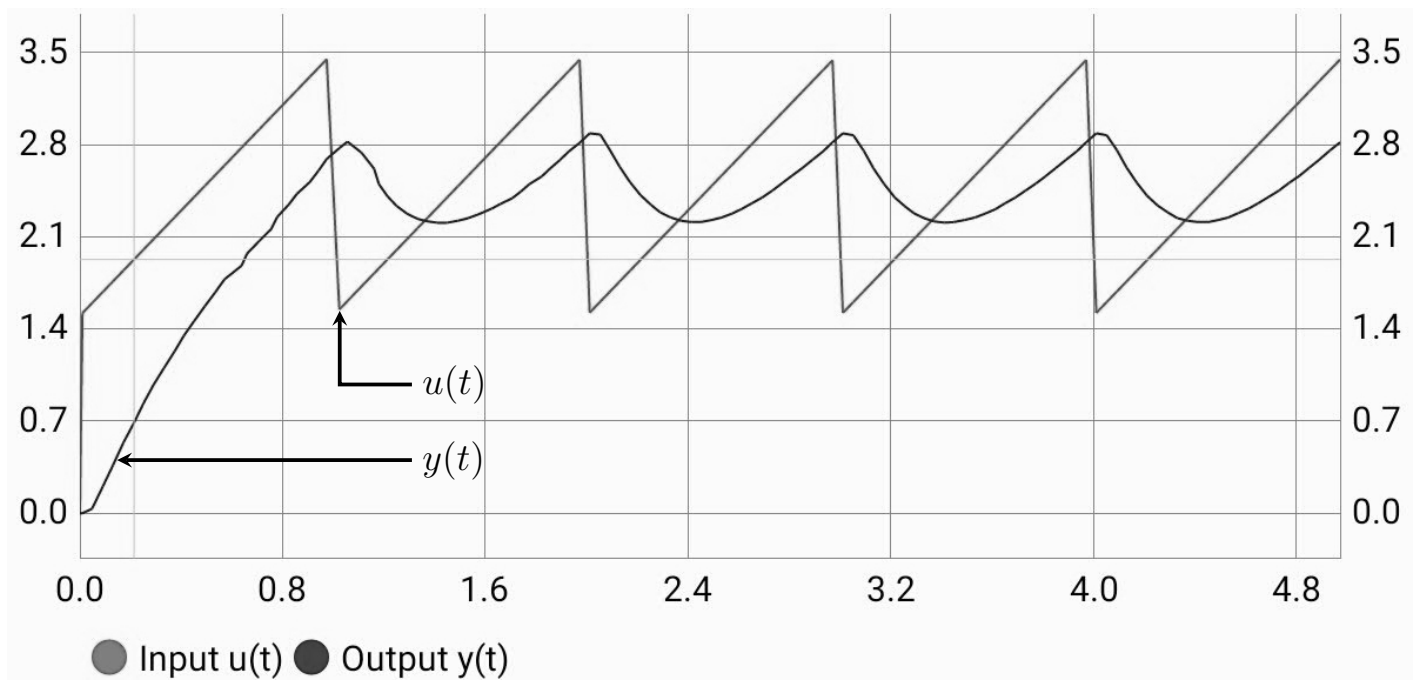
Figure 11: Response of the second-order filter to a sawtooth wave input.
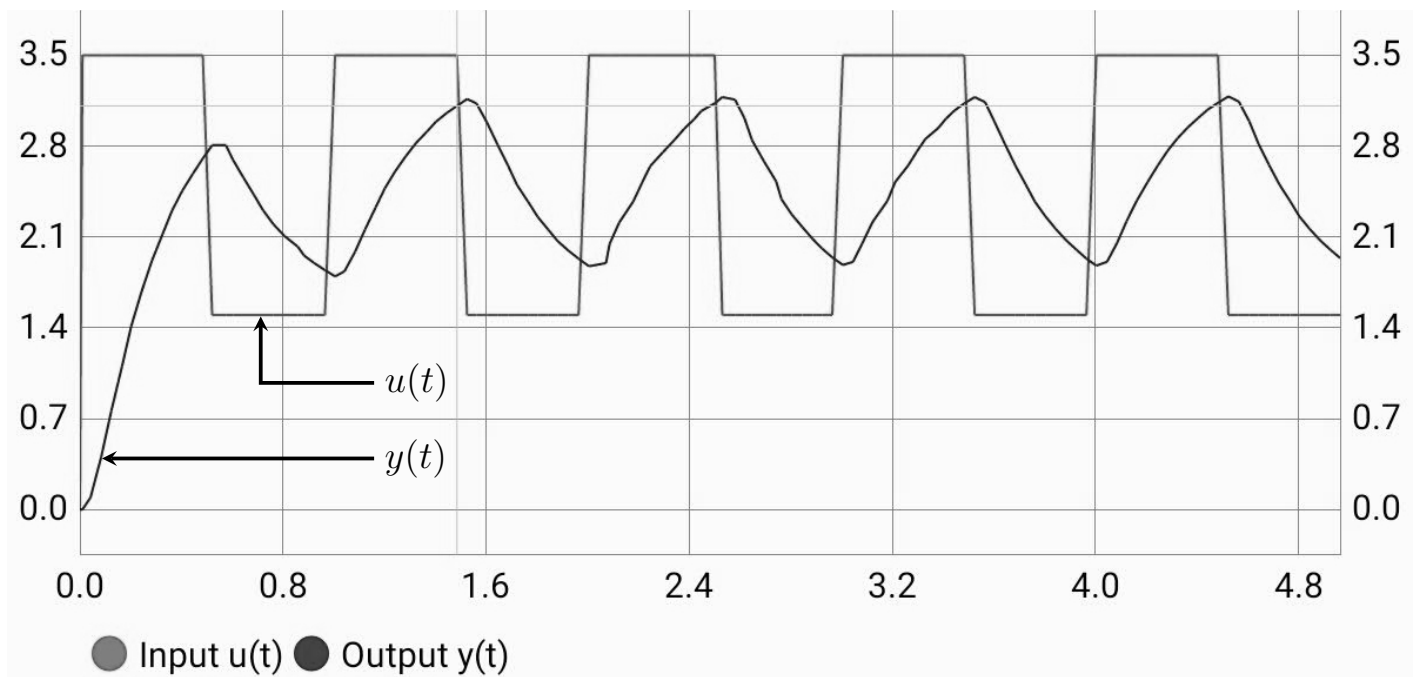


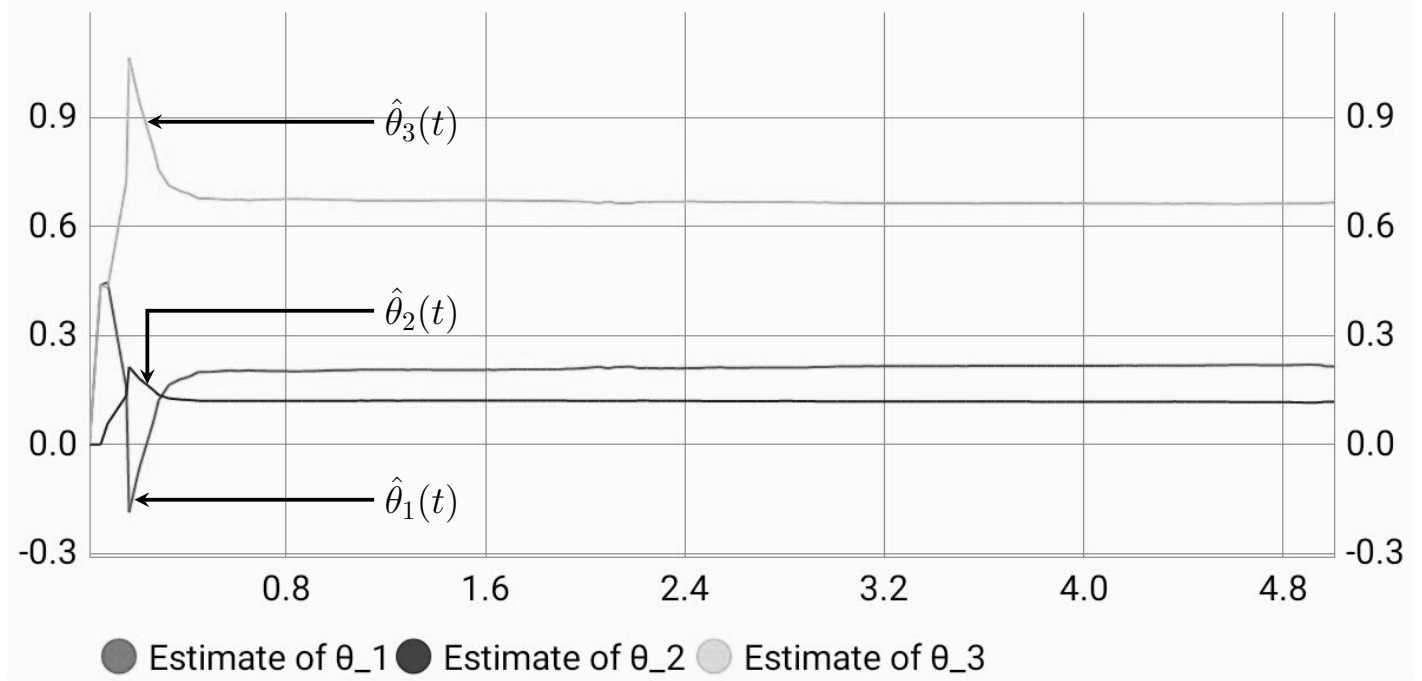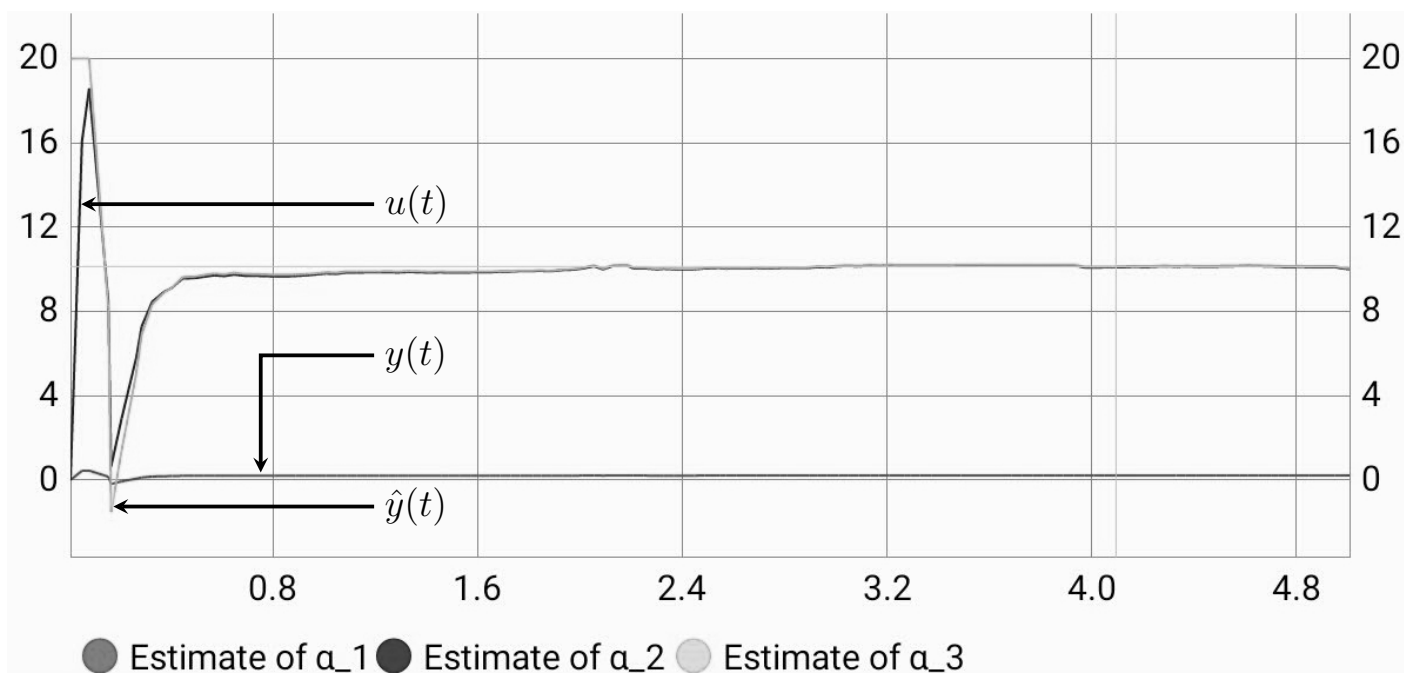Figure 12: Response of the second-order filter to a square wave input.
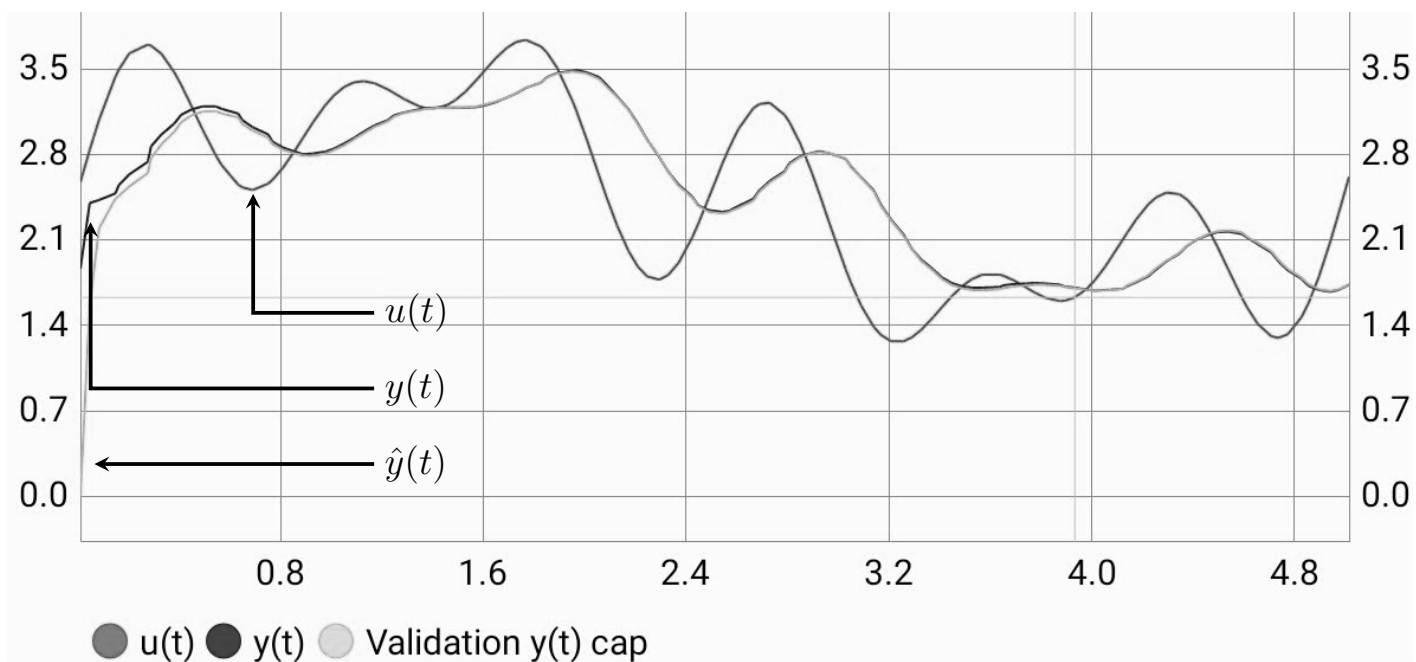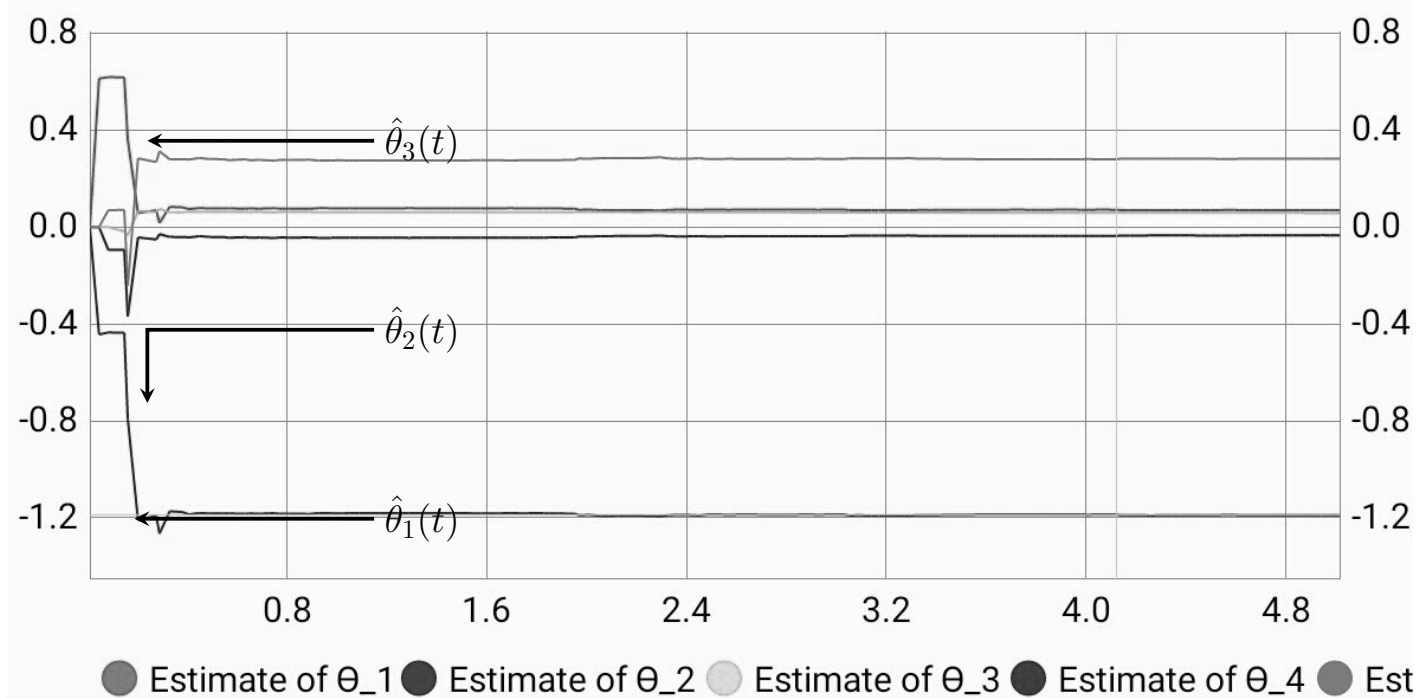
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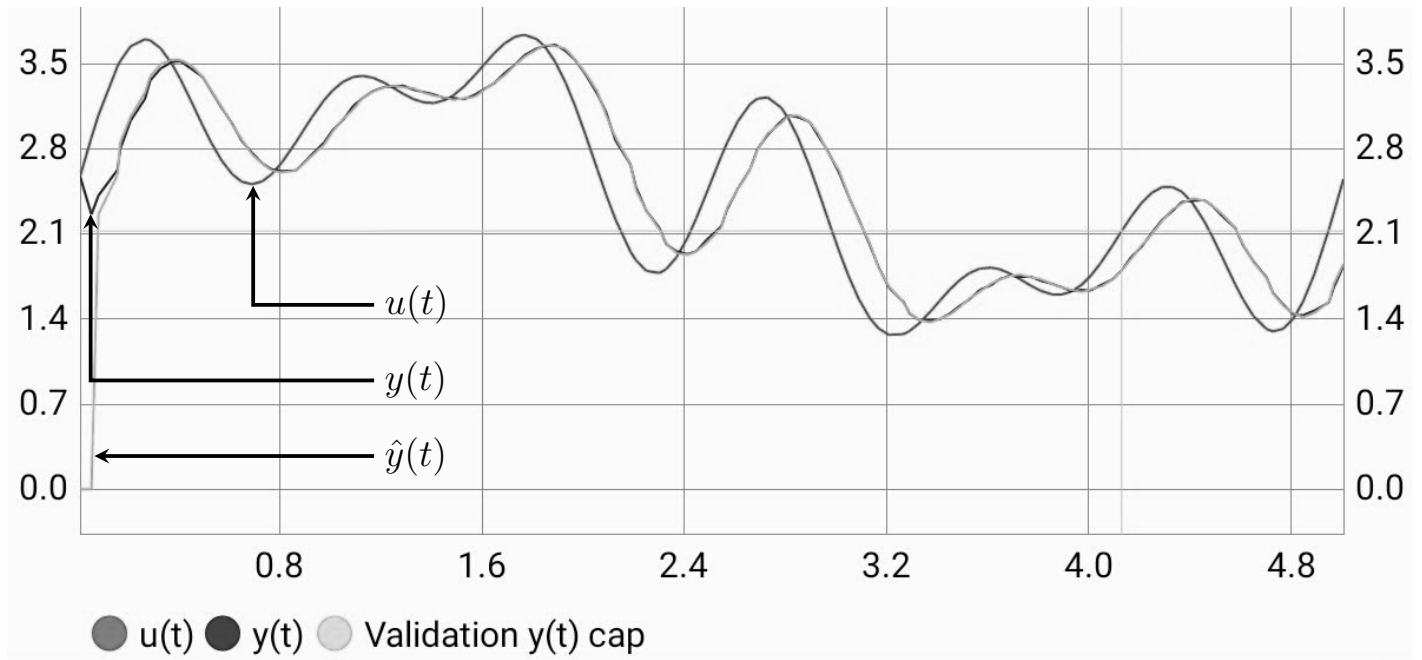
Figure 13: Signals $u(k)$, $y(k)$, $\hat{y}(k)$ and parameters $\hat{\theta}_1$, $\hat{\theta}_2$, $\hat{\theta}_3$.

| Instantaneous values | | | |
|---|---|---|---|
| Time t | 5.007 | s | |
| Actual sampling time | 40.4023 | ms | |
| u(t) | 2.55100 | | |
| y(t) | 1.83594 | | |
| Validation y(t) cap | 1.85209 | | |
| Estimate of θ_1 | 0.214658 | | |
| Estimate of θ_2 | 0.117516 | | |
| Estimate of θ_3 | 0.666384 | | |
| Estimate of α_1 | 0.214658 | | |
| Estimate of α_2 | 10.0028 | | |
| Estimate of α_3 | 10.0462 | | |

Figure 14: Estimates $\hat{\alpha}_1(t)$, $\hat{\alpha}_2(t)$, $\hat{\alpha}_3(t)$, .and instantaneous values of signals and parameters.
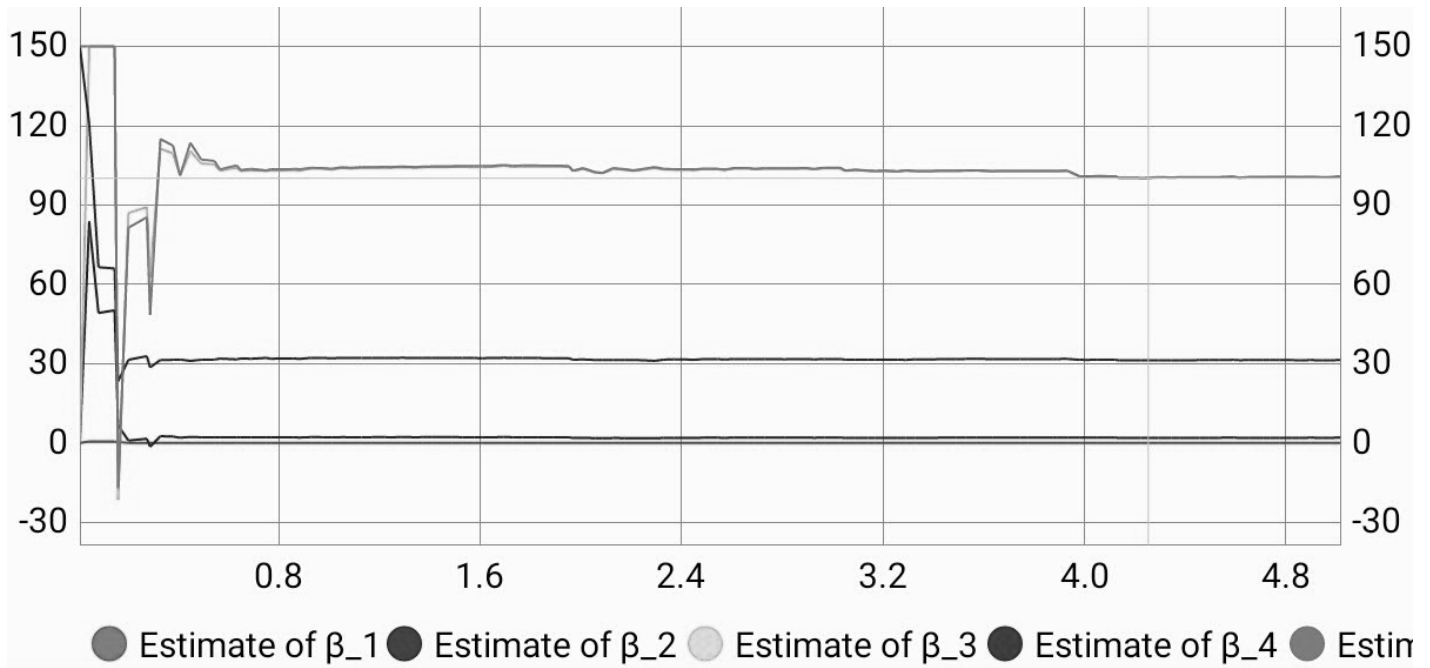
Figure 2: Estimate of Θ



Figure 15: Signals $u(k)$, $y(k)$, $\hat{y}(k)$ and parameters $\hat{\theta}_1$, $\hat{\theta}_2$, $\hat{\theta}_3$, $\hat{\theta}_4$ and $\hat{\theta}_5$.

| Instantaneous values | | |
|---|---|---|
| Time t | 5.016 | s |
| Actual sampling time | 40.4788 | ms |
| u(t) | 2.61643 | |
| y(t) | 1.73340 | |
| Validation y(t) cap | 1.73523 | |
| Estimate of Θ_1 | 0.0692599 | |
| Estimate of Θ_2 | -0.0343029 | |
| Estimate of Θ_3 | 0.0572122 | |
| Estimate of Θ_4 | -1.18859 | |
| Estimate of Θ_5 | 0.280906 | |
| Estimate of β_1 | 0.0692599 | |
| Estimate of β_2 | 2.00433 | |
| Estimate of β_3 | 100.661 | |
| Estimate of β_4 | 31.3661 | |
| Estimate of β_5 | 100.821 | |

Figure 16: Estimates $\hat{\beta}_1$, $\hat{\beta}_2$, $\hat{\beta}_3$, $\hat{\beta}_4$, $\hat{\beta}_5$, and instantaneous values of signals and parameters.
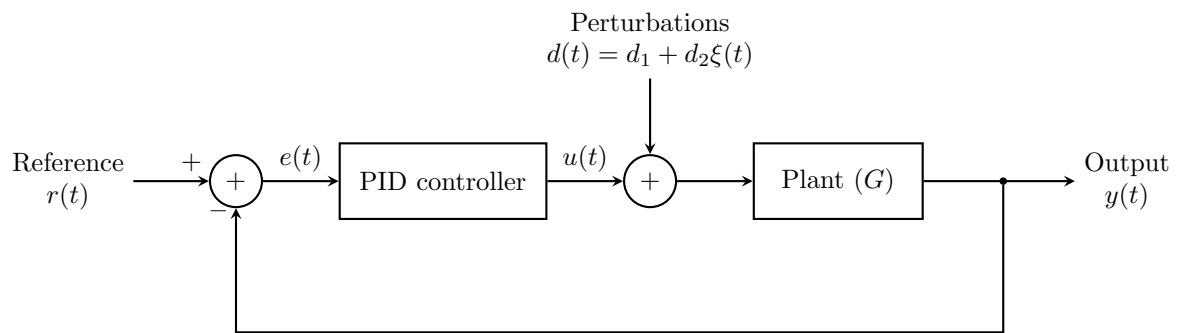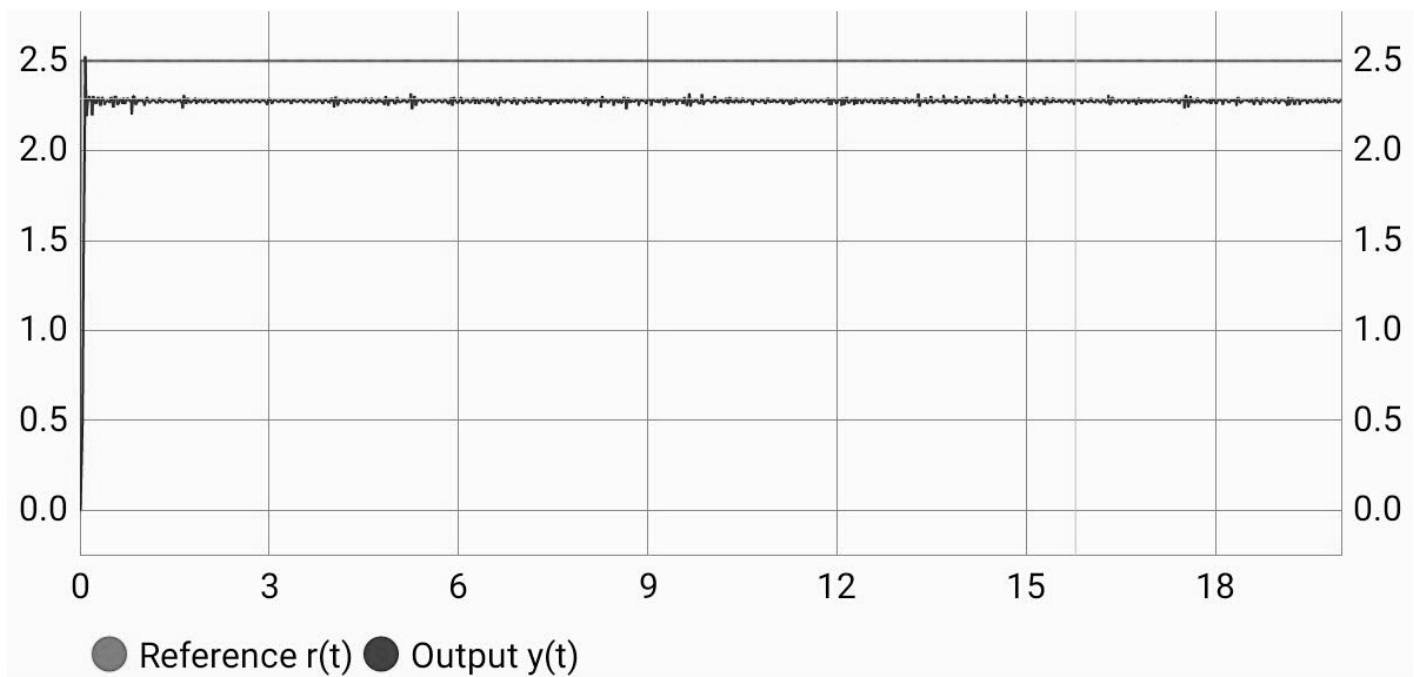
Figure 17: Closed loop system with a PID Controller
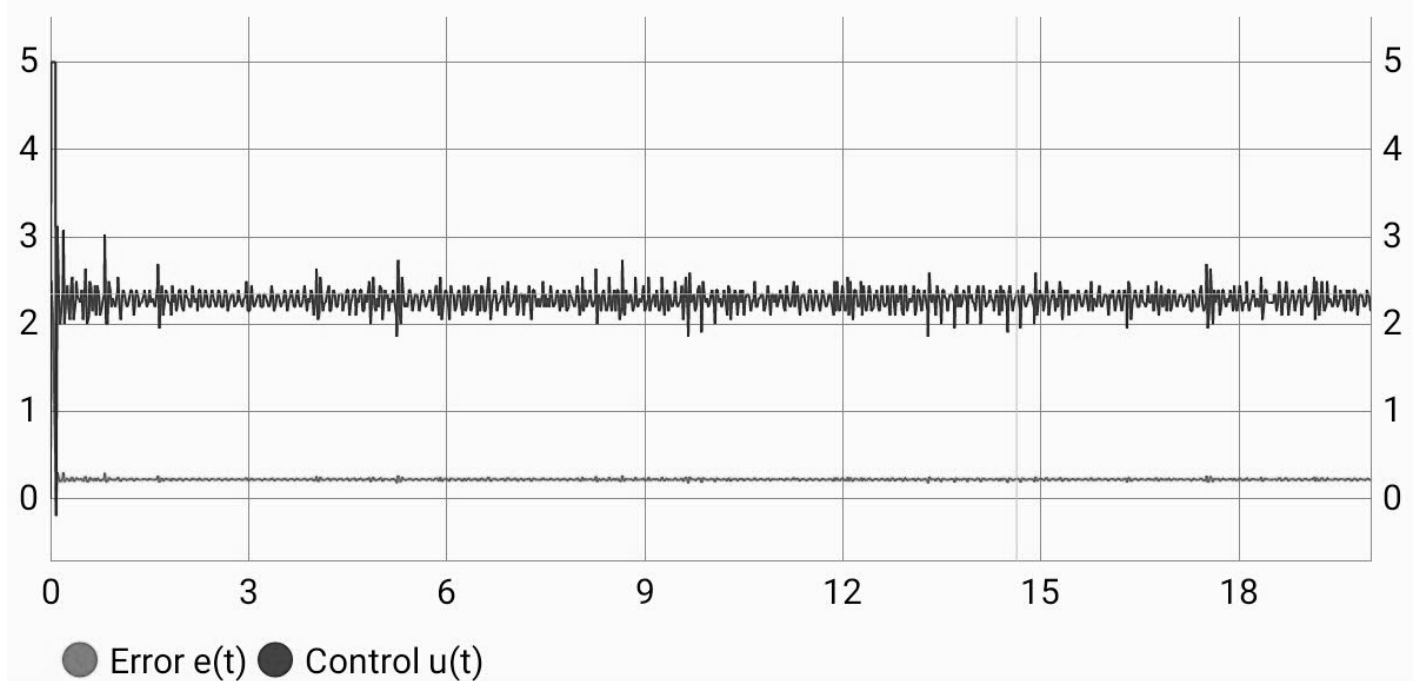
Figure 2: Error e(t) and Control u(t)



Figure 18: Signals $r(k)$, $y(k)$, $e(k)$ and $u(k)$ of the closed-loop system with $K_P = 10$, $K_I = 0$, and $K_D = 0$.
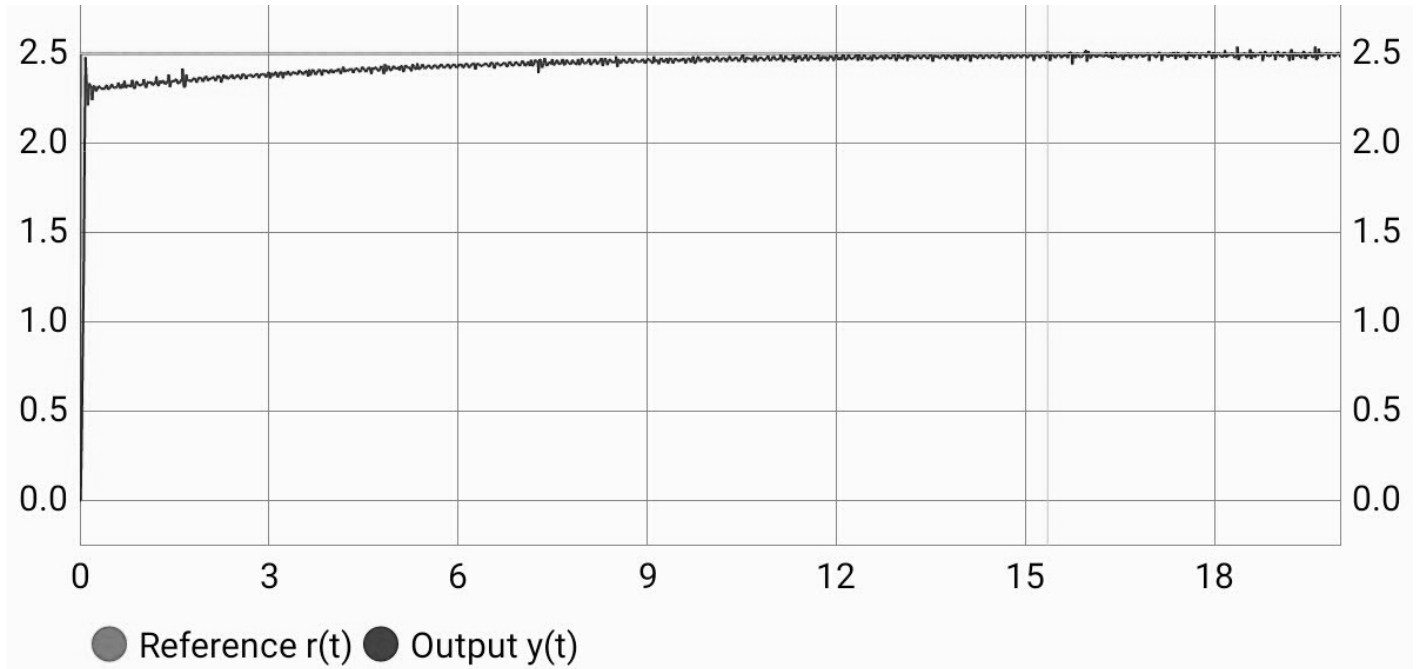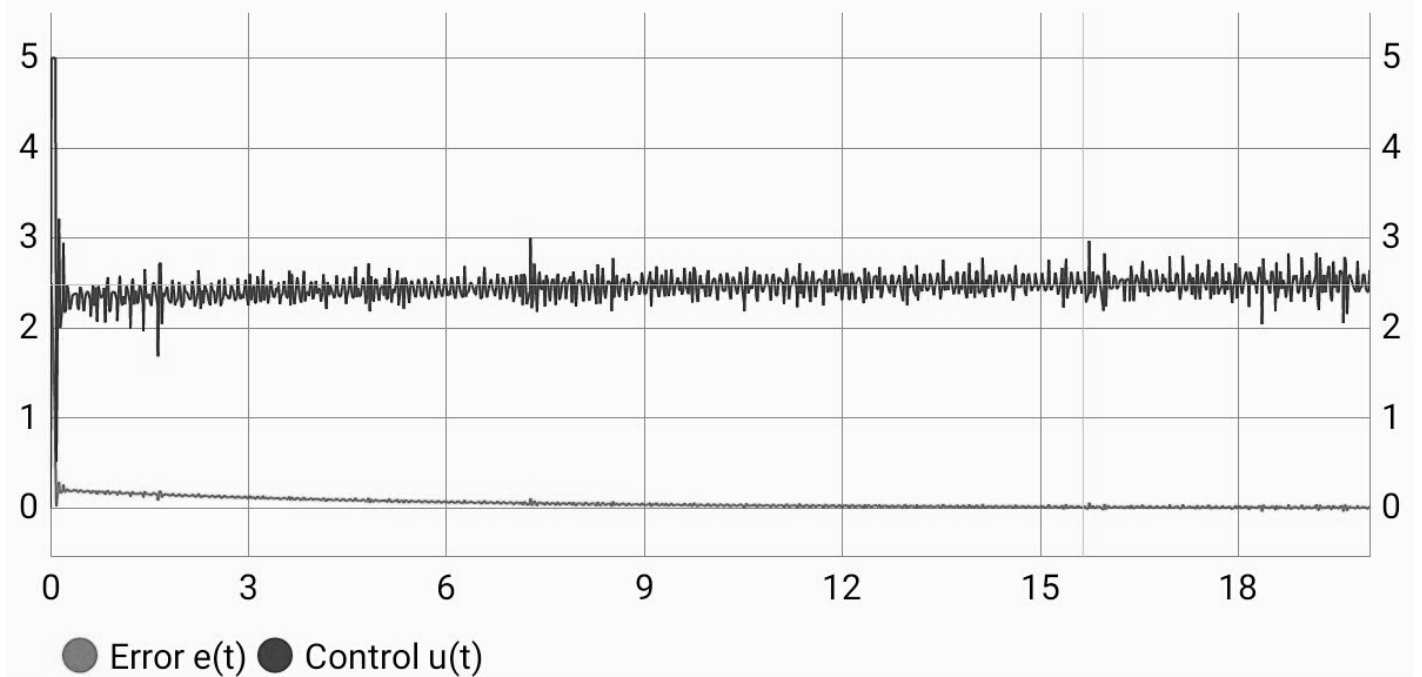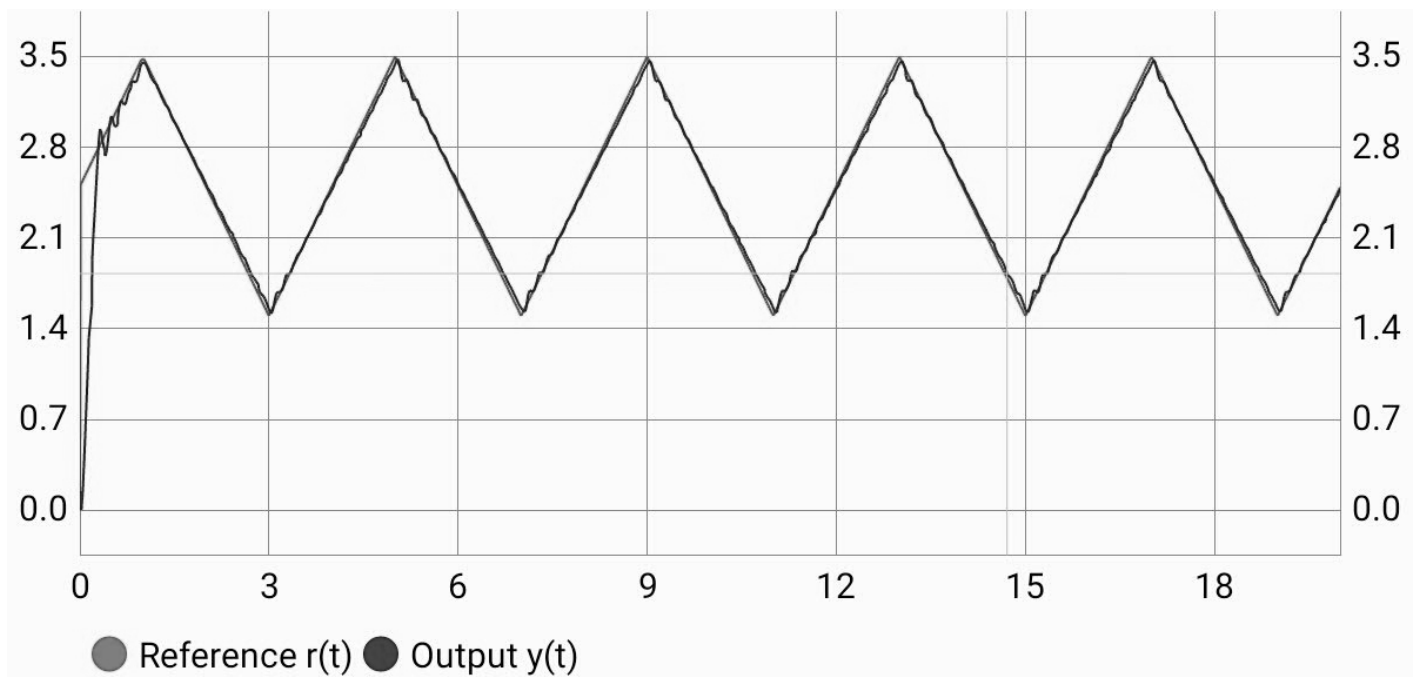
Figure 19: Signals $r(k)$, $y(k)$, $e(k)$ and $u(k)$ of the closed-loop system with $K_P = 10$, $K_I = 2$, and $K_D = 0$.
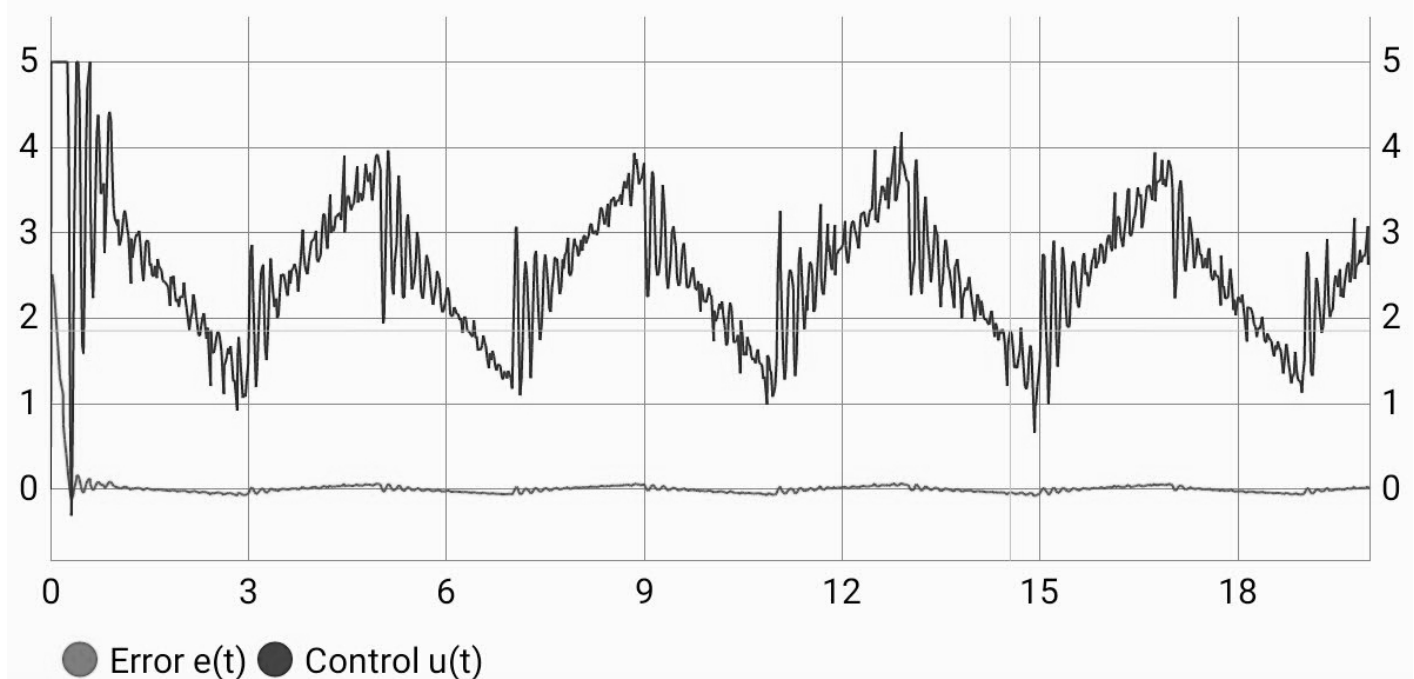
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Figure 20: Signals $r(k)$, $y(k)$, $e(k)$ and $u(k)$ of the closed-loop system with $K_P = 20$, $K_I = 5$, and $K_D = 0.1$.