



# Implementación de sistemas de control de calefacción en vehículos de transporte público



Francisco Vázquez

**Dpto. Ingeniería Eléctrica y Automática**



# Francisco Vázquez



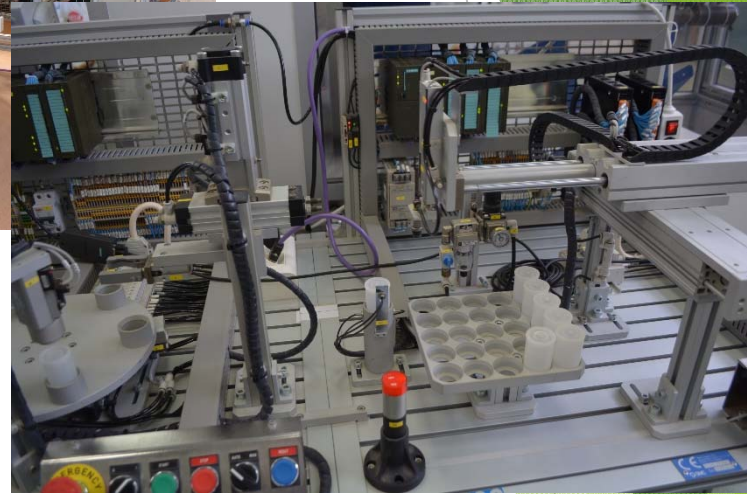
- ▶ Doctor en Ciencias Físicas
- ▶ Profesor Titular, Universidad de Córdoba
  - Área de Ingeniería de Sistemas y Automática
  - Dpto. de Ingeniería Eléctrica y Automática
  - Escuela Politécnica Superior de Córdoba
  
- ▶ Director del Máster Dual en Industria 4.0
  - <http://www.uco.es/estudios/postgrado/masterindustria/>
  
- ▶ Responsable del Grupo de Investigación PRINIA (TEP-226)
  - <http://www.uco.es/grupos/prinia>
  
- ▶ Email: [fvazquez@uco.es](mailto:fvazquez@uco.es)
  
- ▶ ORCID: <http://orcid.org/0000-0003-4544-6084>



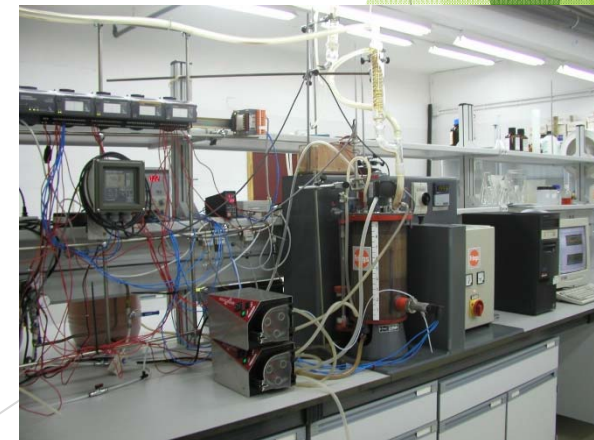
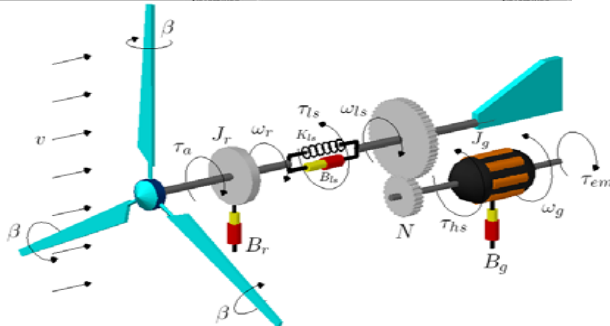
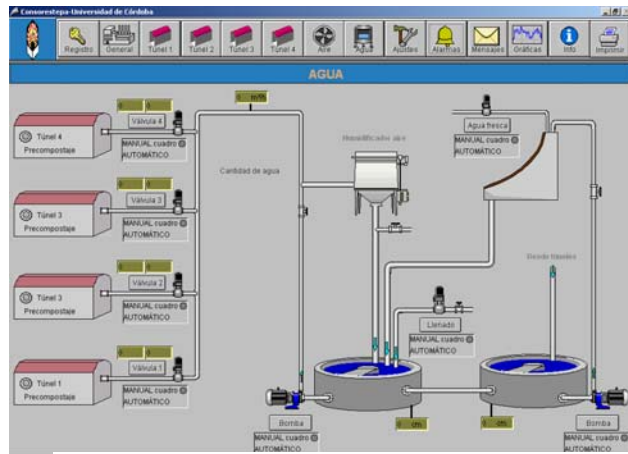
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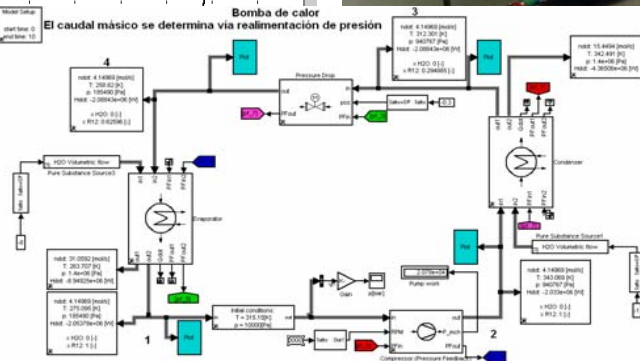
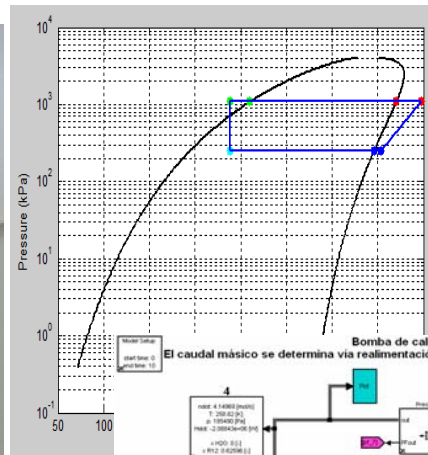
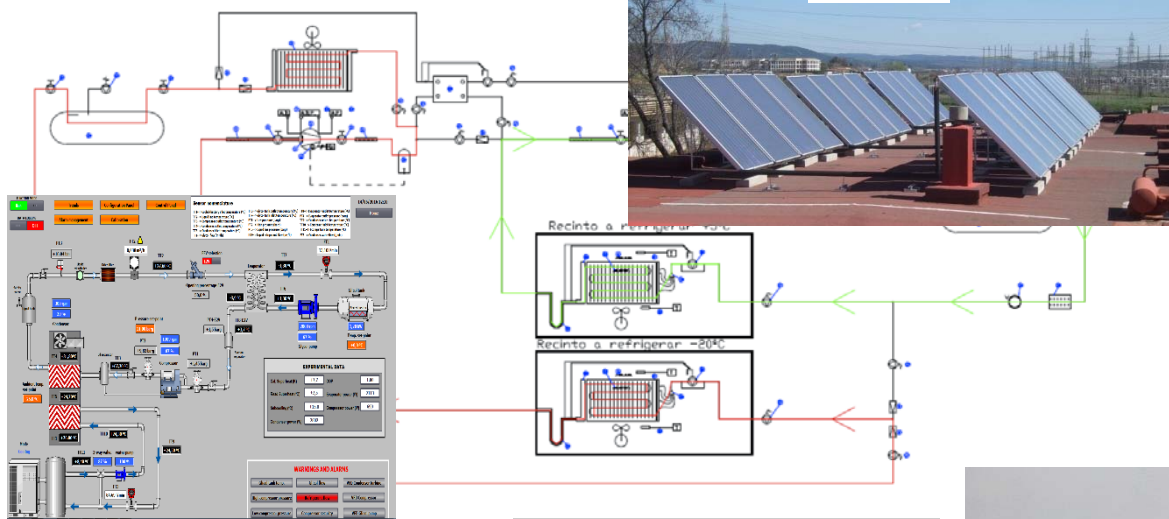
UNIVERSIDAD  
DE  
CÓRDOBA



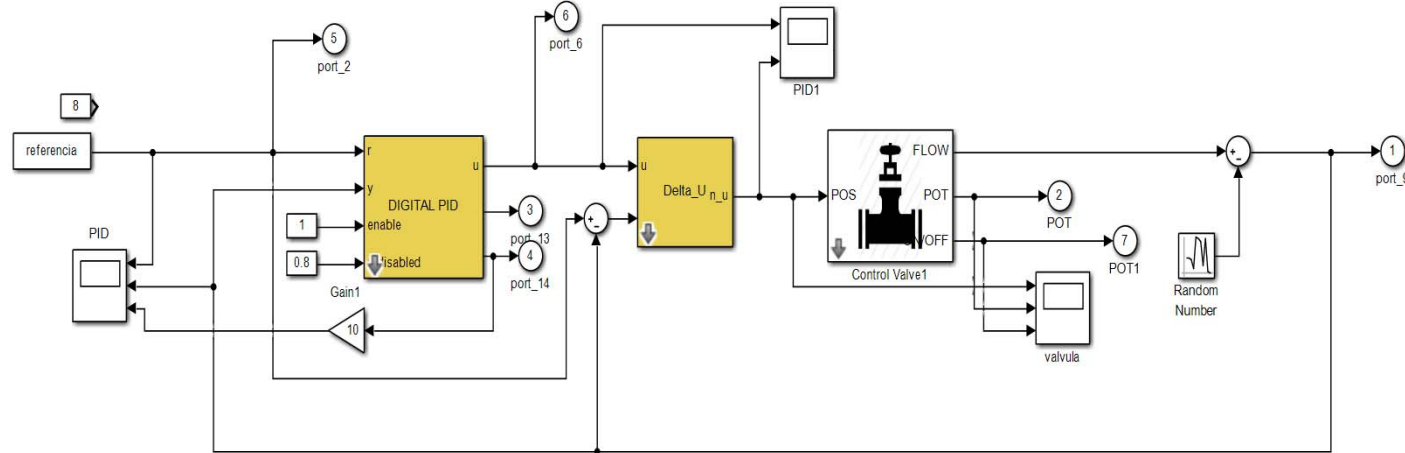
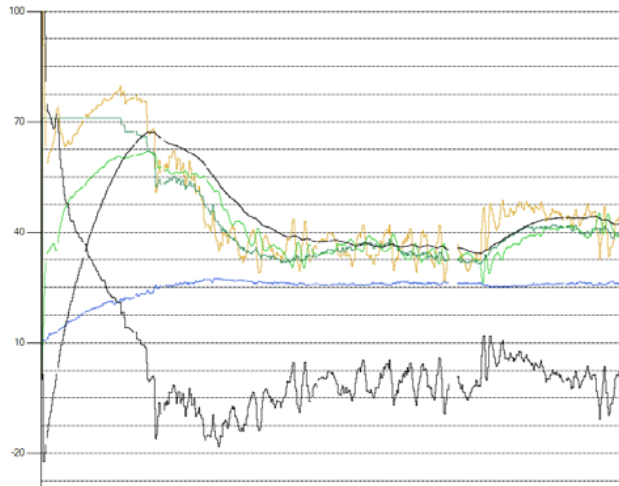
# Proyectos I+D+T



# Proyectos I+D+T



# Proyectos I+D+T



# INDICE

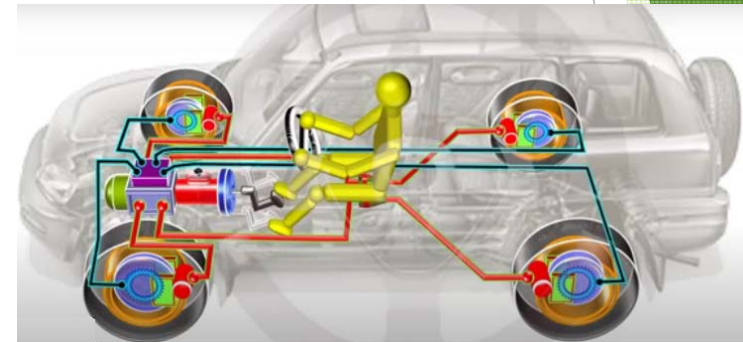
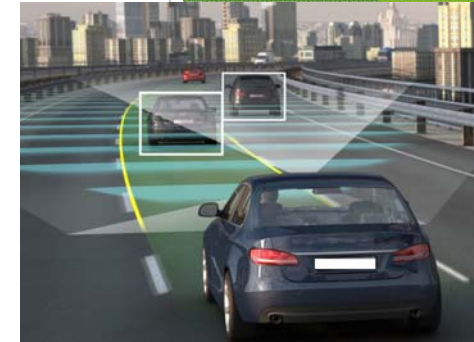
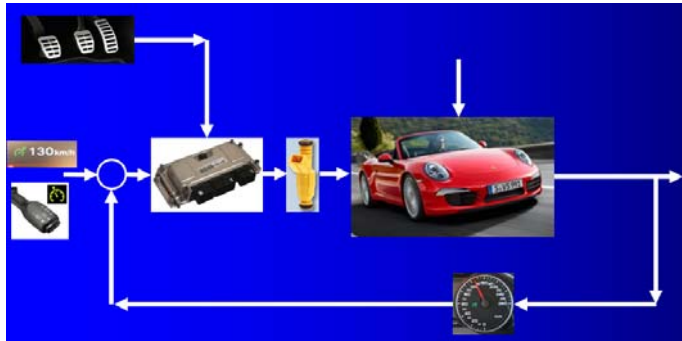
- ▶ Introducción
- ▶ Componentes del sistema de calefacción
- ▶ La válvula de control
  - Características
  - La válvula en LC
- ▶ Ensayos a bordo
- ▶ Trabajo actual

# INDICE

- ▶ **Introducción**
- ▶ Componentes del sistema de calefacción
- ▶ La válvula de control
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  - La válvula en LC
- ▶ Ensayos a bordo
- ▶ Trabajo actual



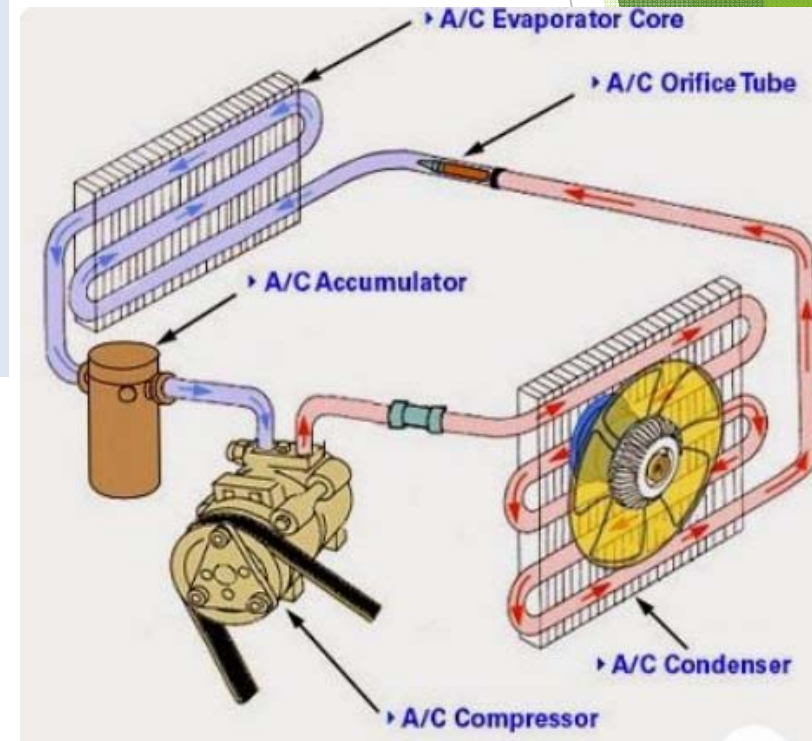
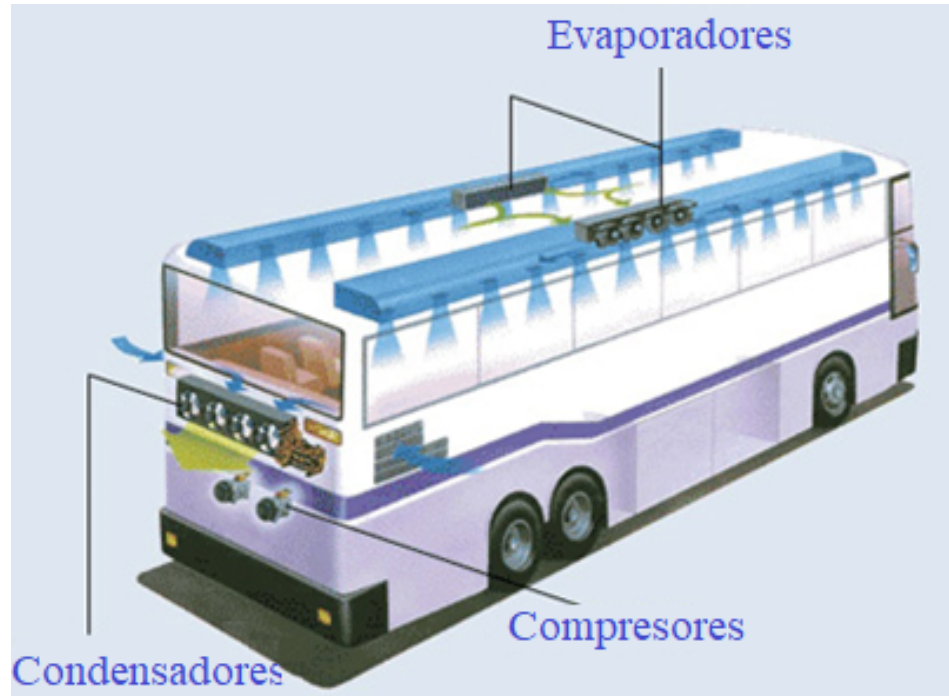
# IT en vehículos



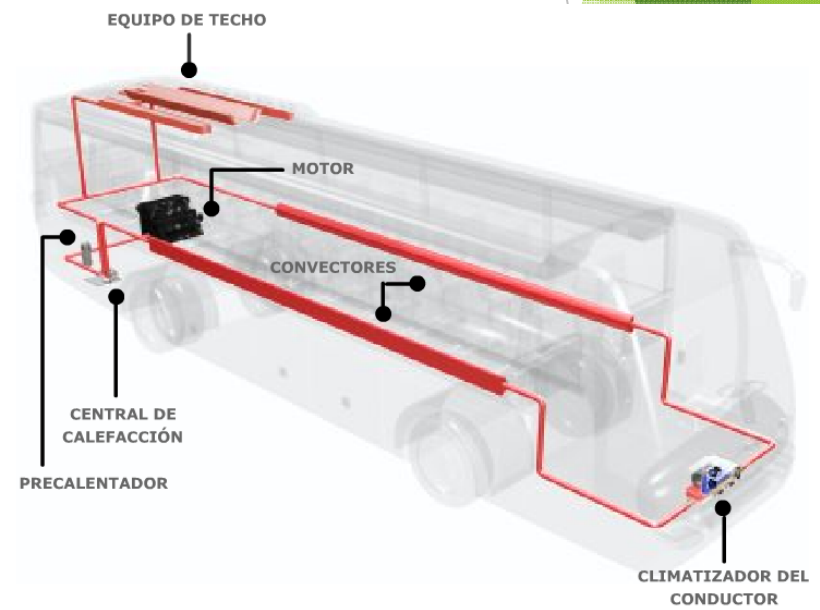
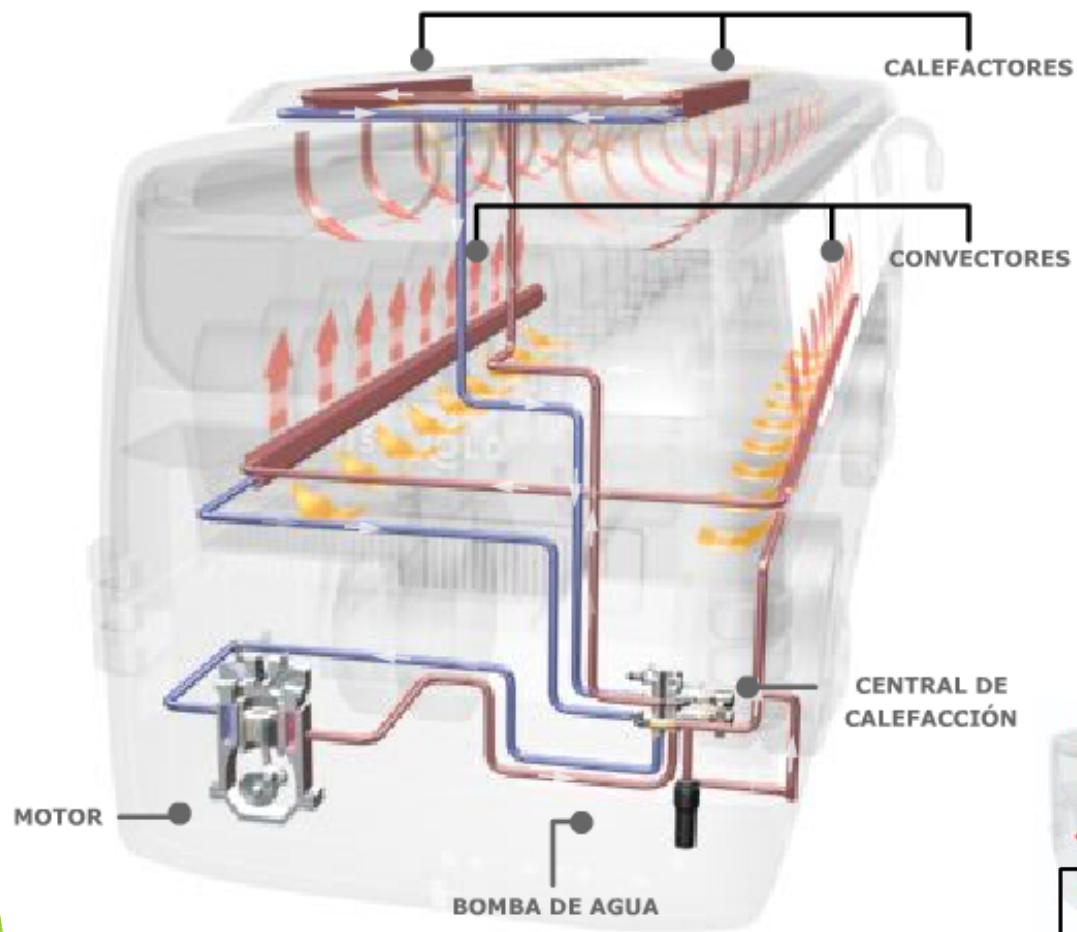
# HVAC en vehículos



# Generación de frío



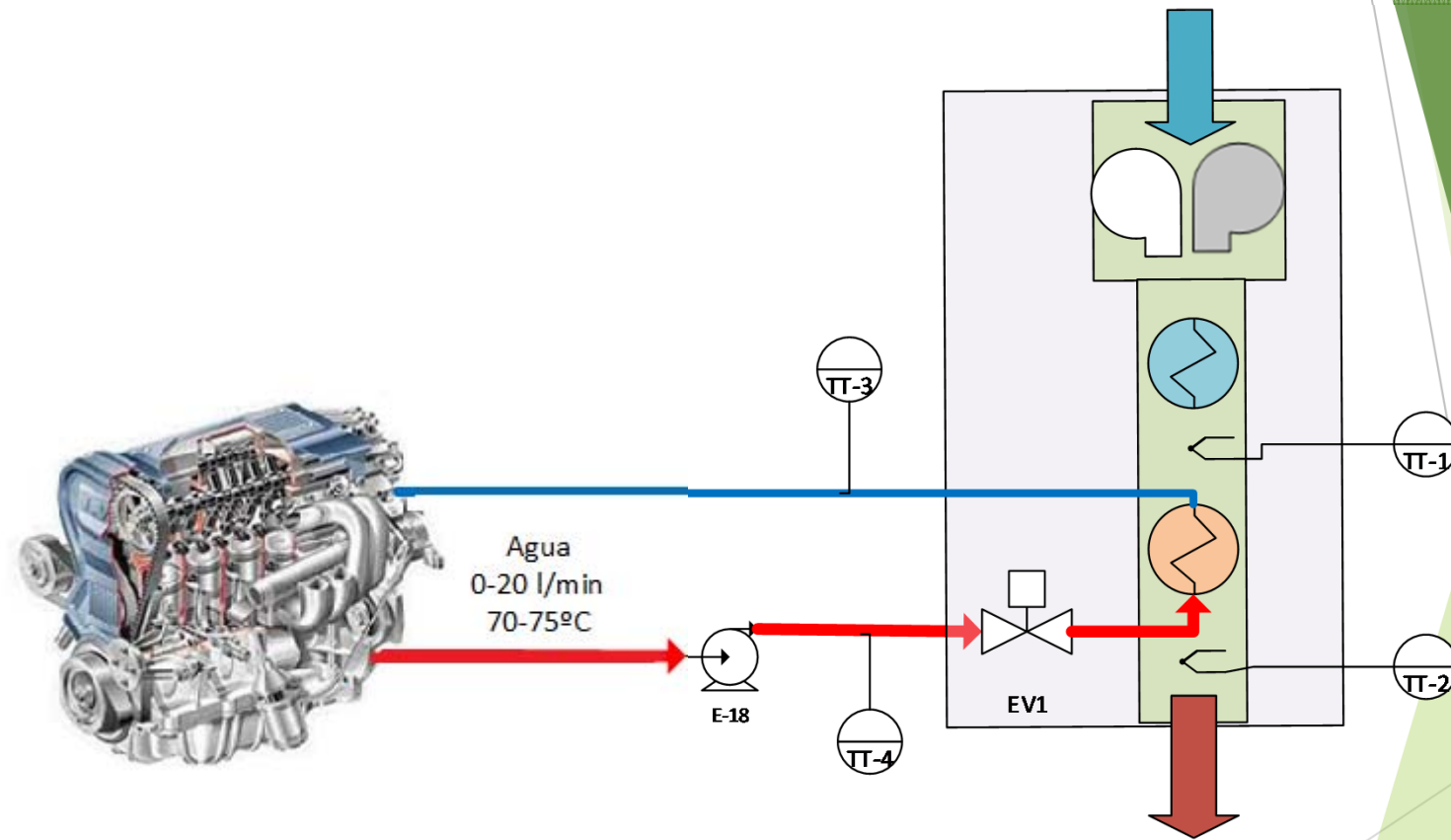
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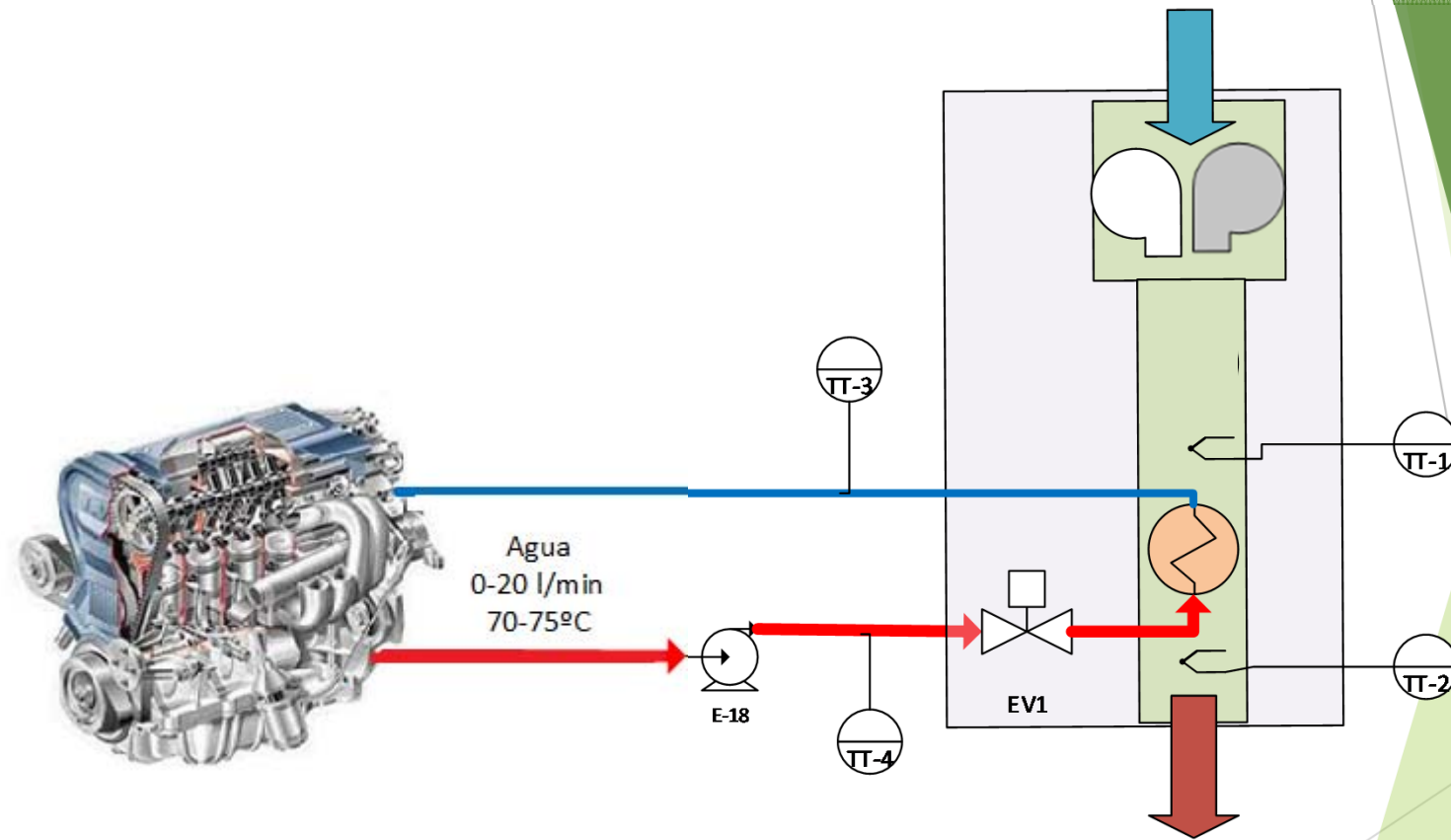
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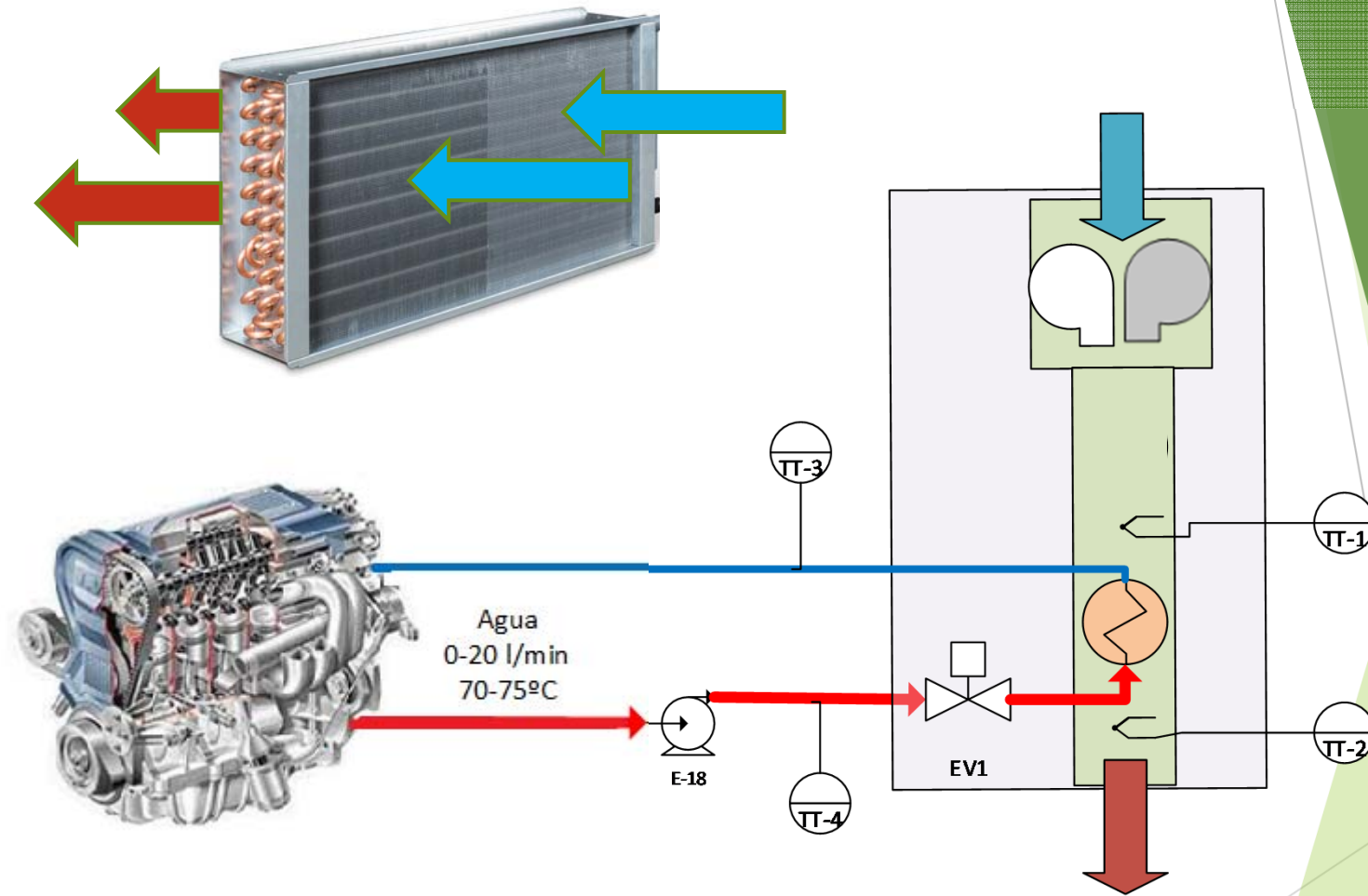
# Calefacción



# Calefacción

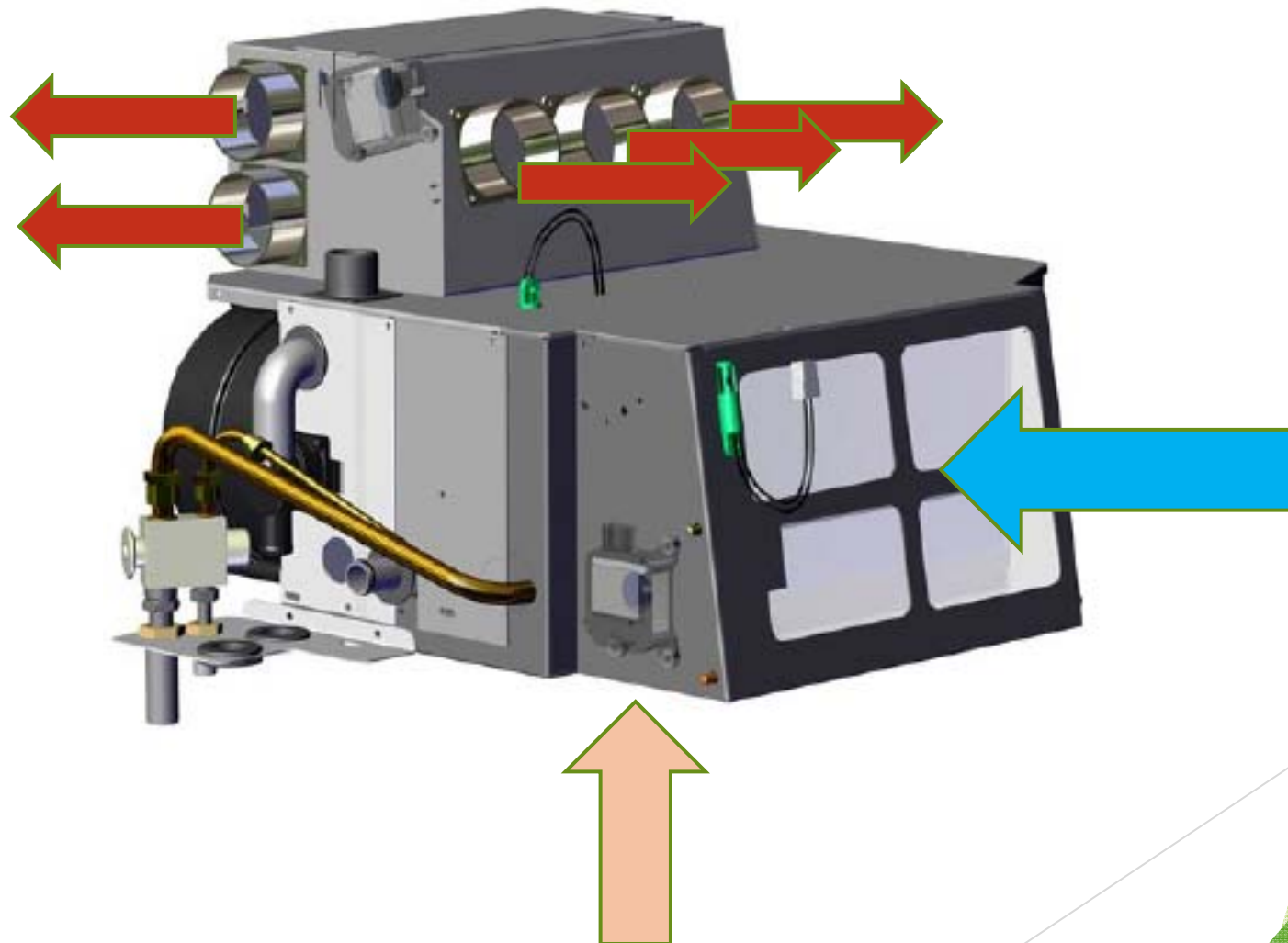


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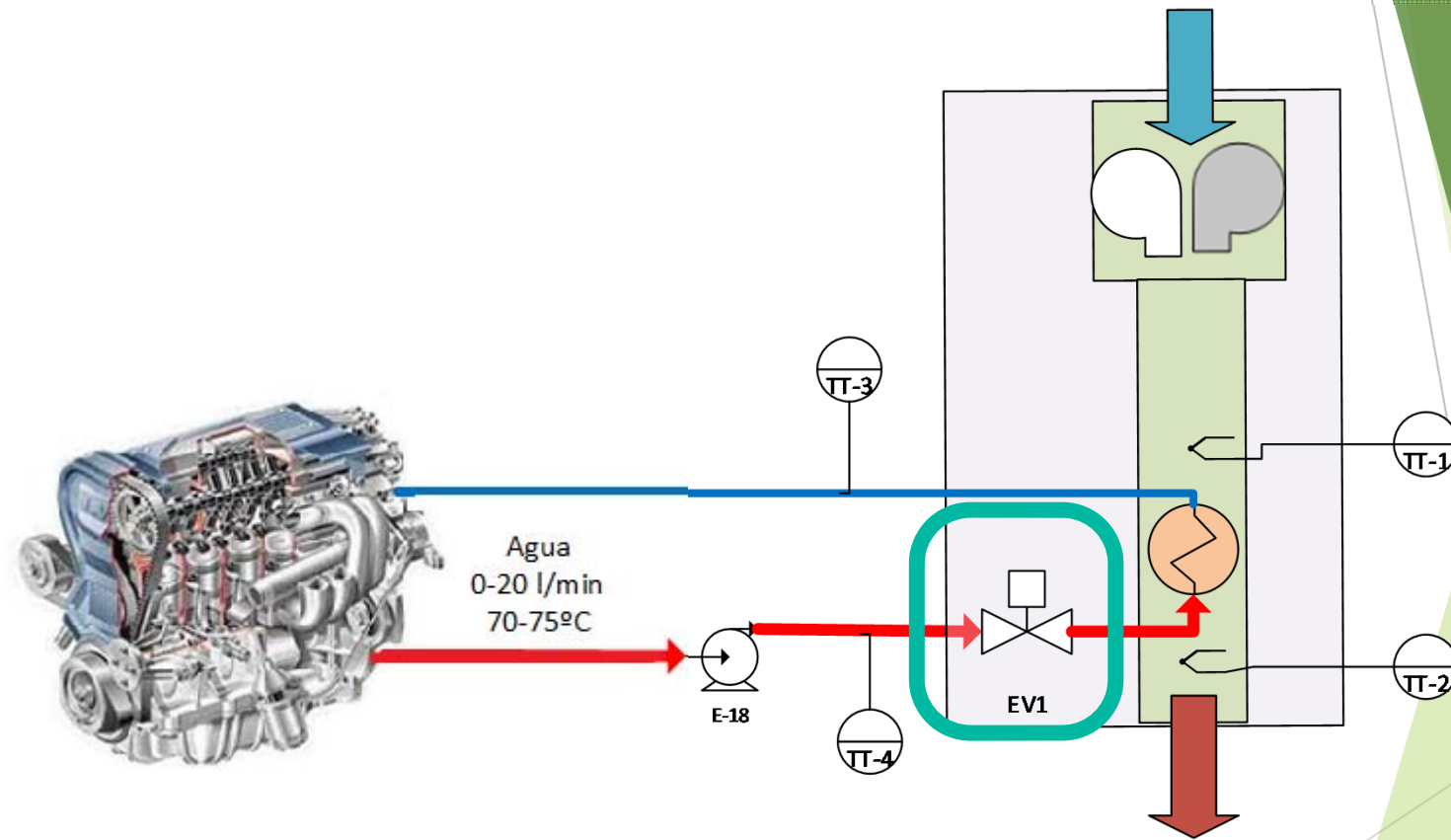
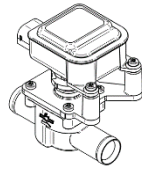




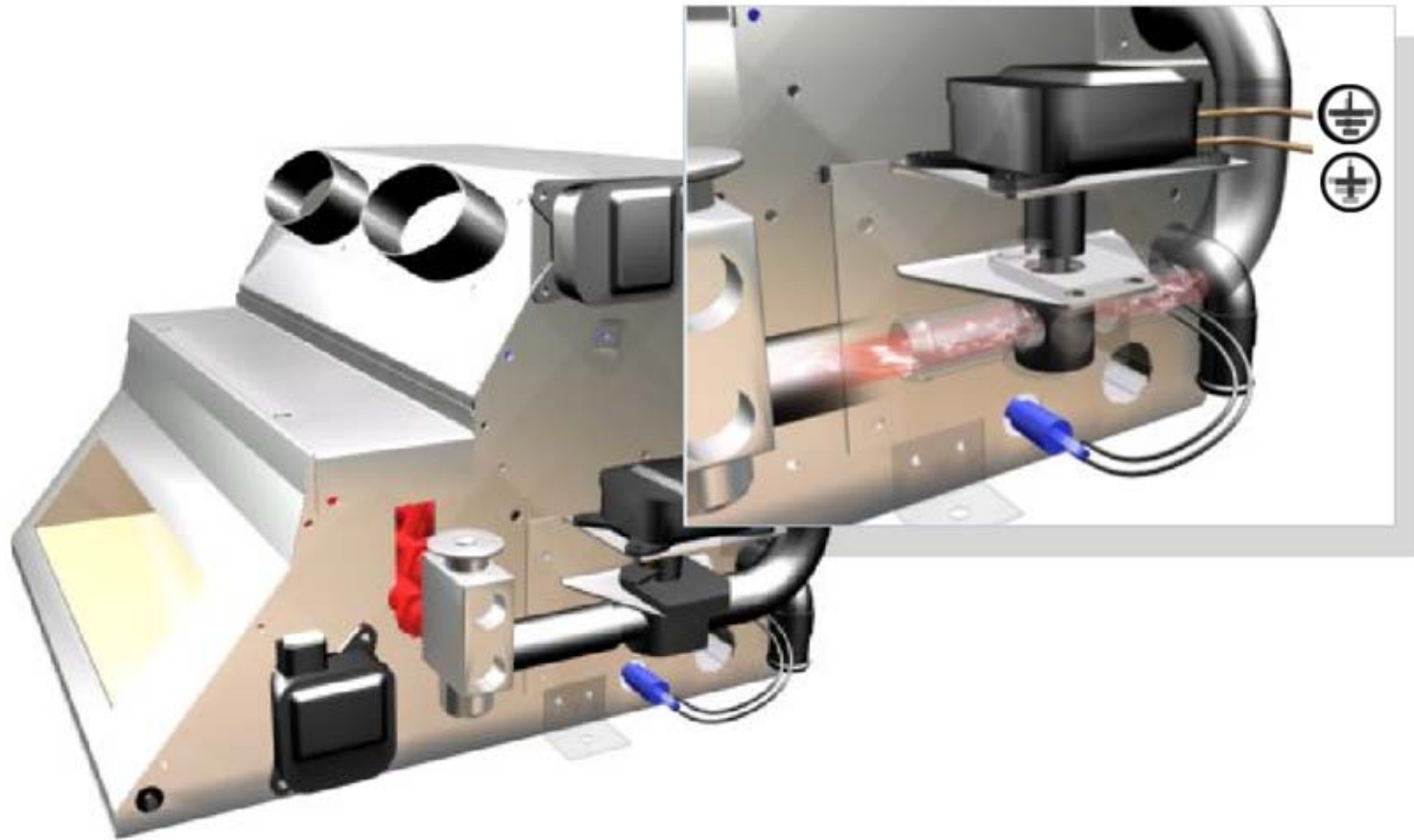
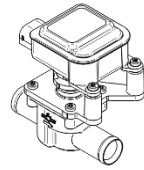
# Calefacción



# La válvula



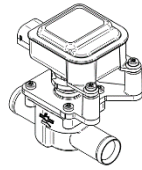
# La válvula



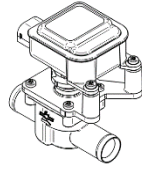
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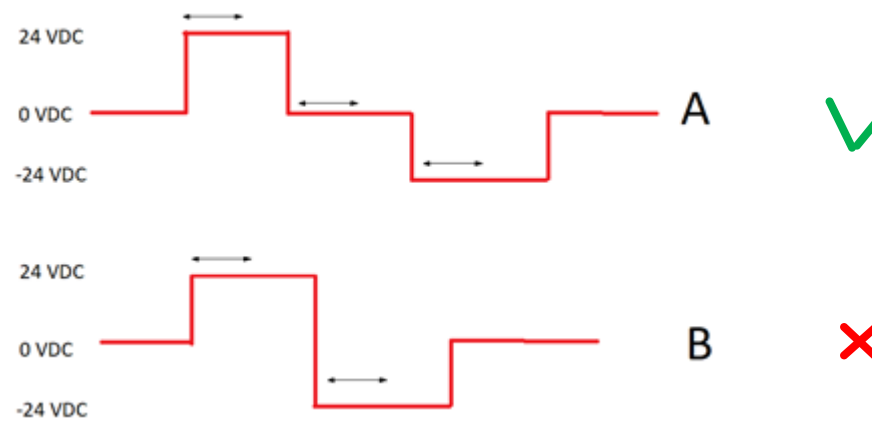
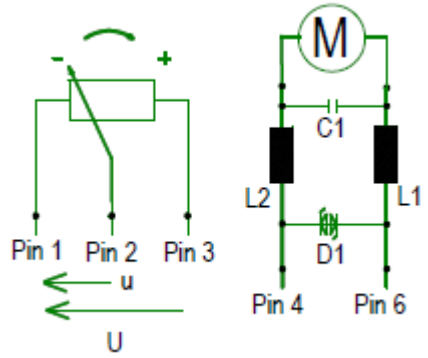
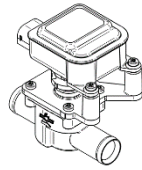
# La válvula



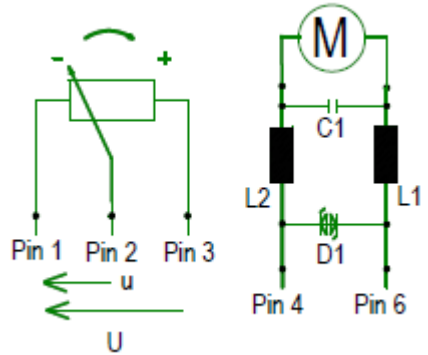
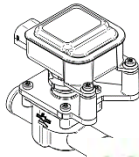
# La válvula



# La válvula



# La válvula

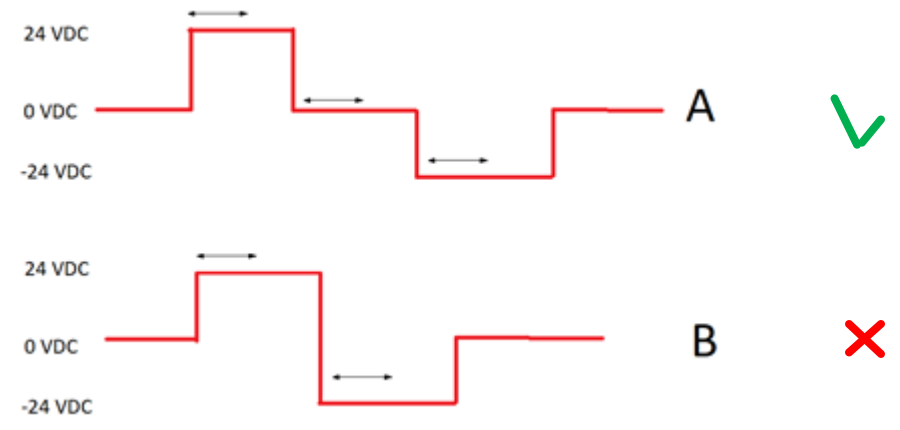


```

% ABRIENDO
if diferencia > limite_3 & (estado_anterior==11 | estado_anterior==0)
    estado=11;
elseif diferencia >= limite_2 & (diferencia <= limite_3) ...
    & (estado_anterior==11 | (estado_anterior==12 & salida_TON2) ...
    | estado_anterior==0)
    estado =12;
elseif diferencia > limite_1 & (diferencia < limite_2) & ...
    (estado_anterior==11 | estado_anterior==12 | ...
    (estado_anterior==13 & salida_TON3) | estado_anterior==0)
    estado =13;

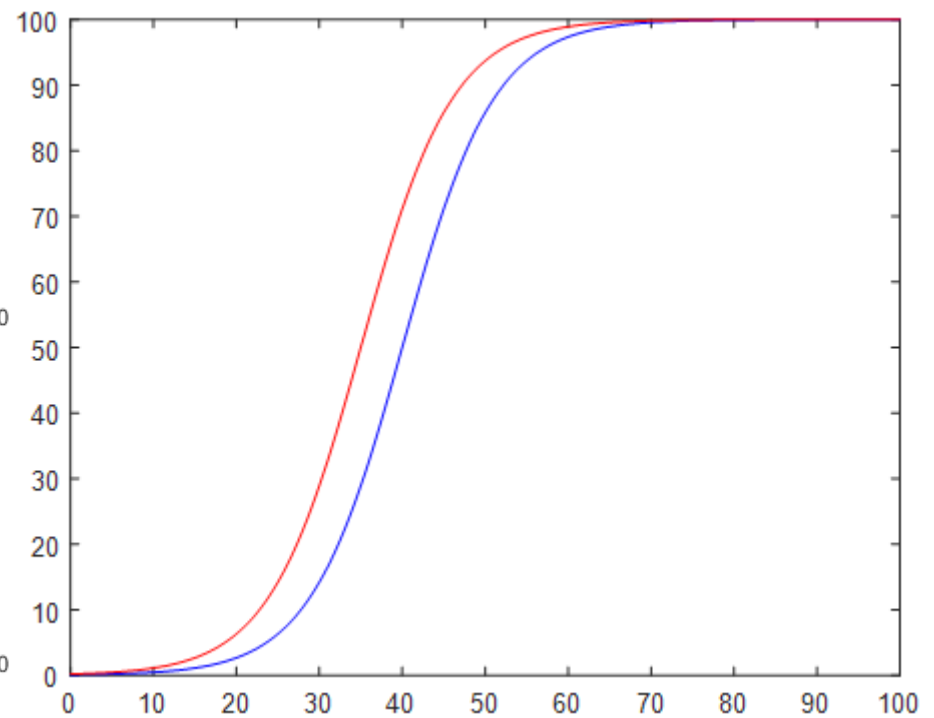
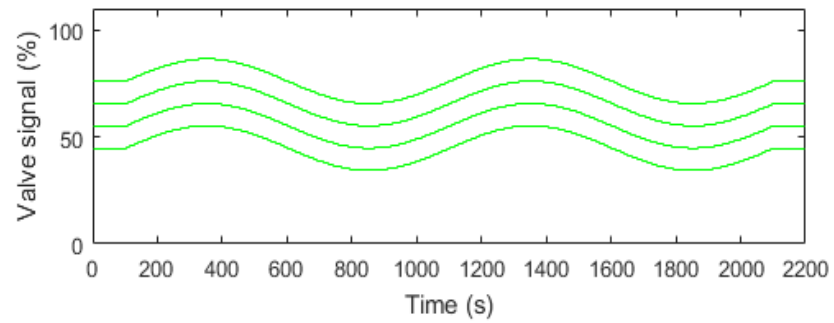
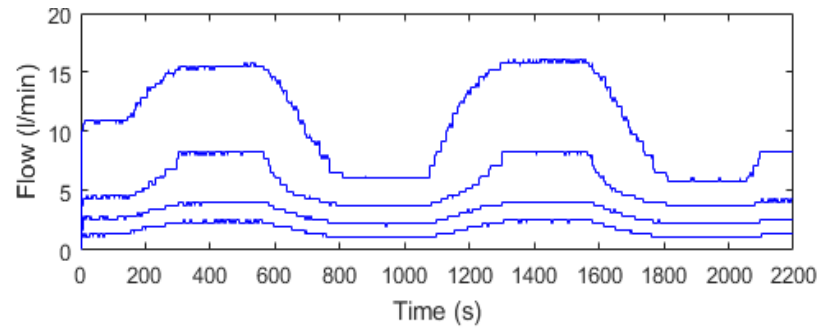
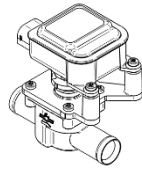
% CERRANDO
elseif -diferencia > limite_3 & (estado_anterior==11 | estado_anterior==0)
    estado=-11;
elseif -diferencia >= limite_2 & (-diferencia <= limite_3) ...
    & (estado_anterior==11 | (estado_anterior==12 & salida_TON2) ...
    | estado_anterior==0)
    estado=-12;

```

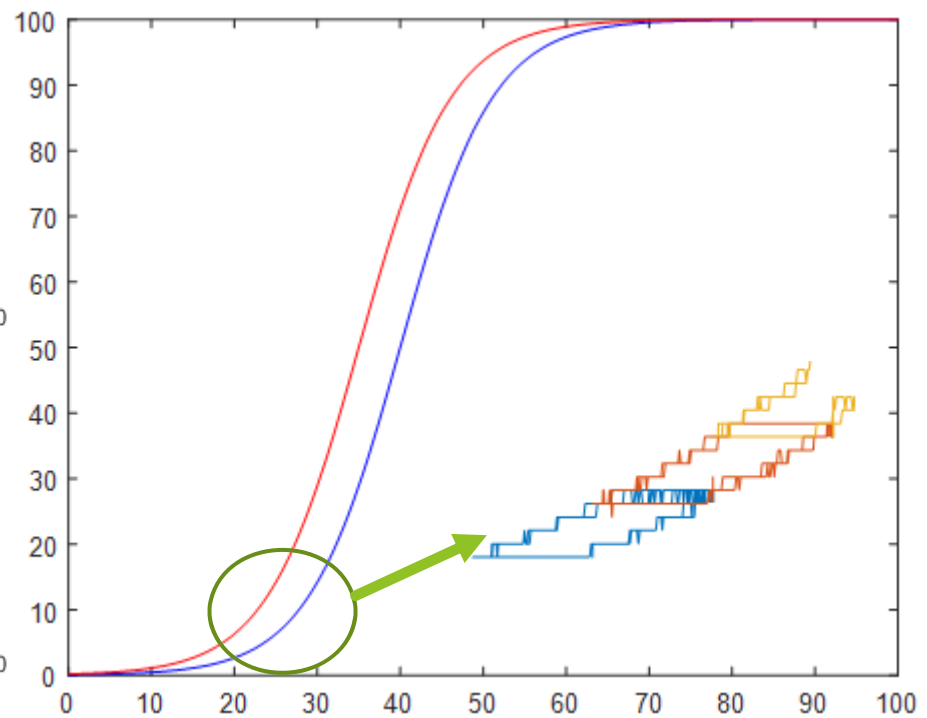
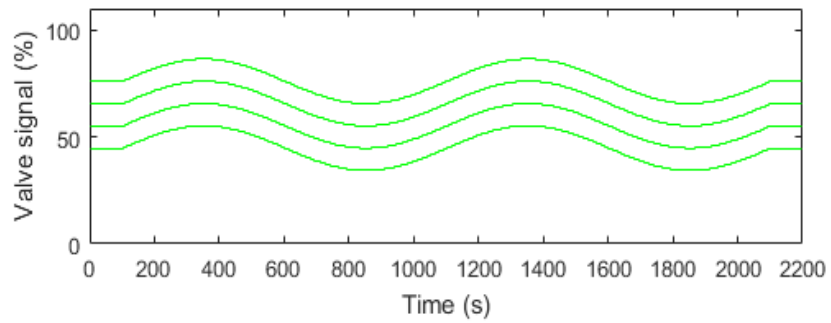
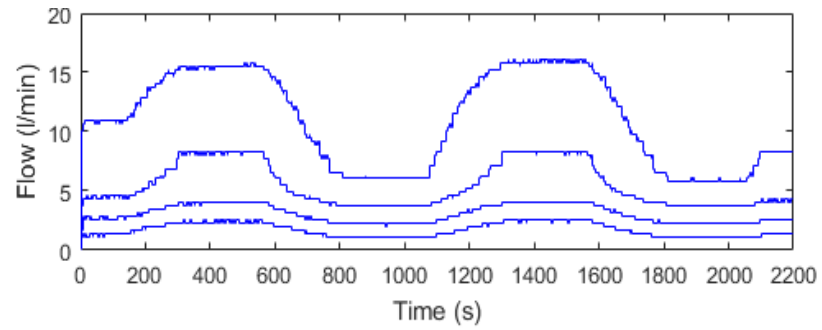
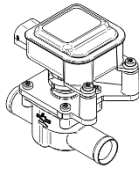




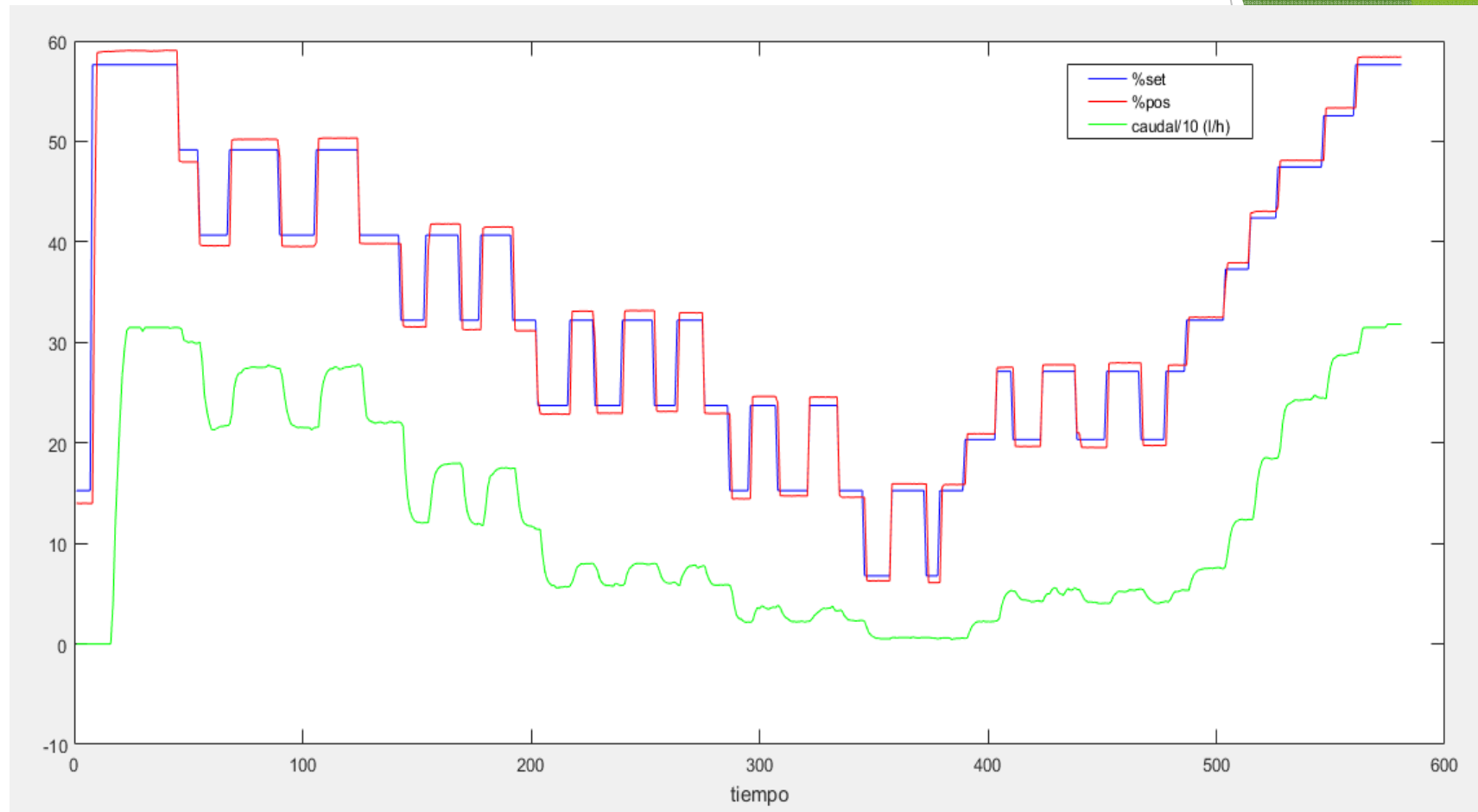
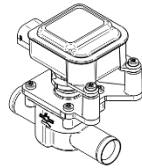
# La válvula



# La válvula

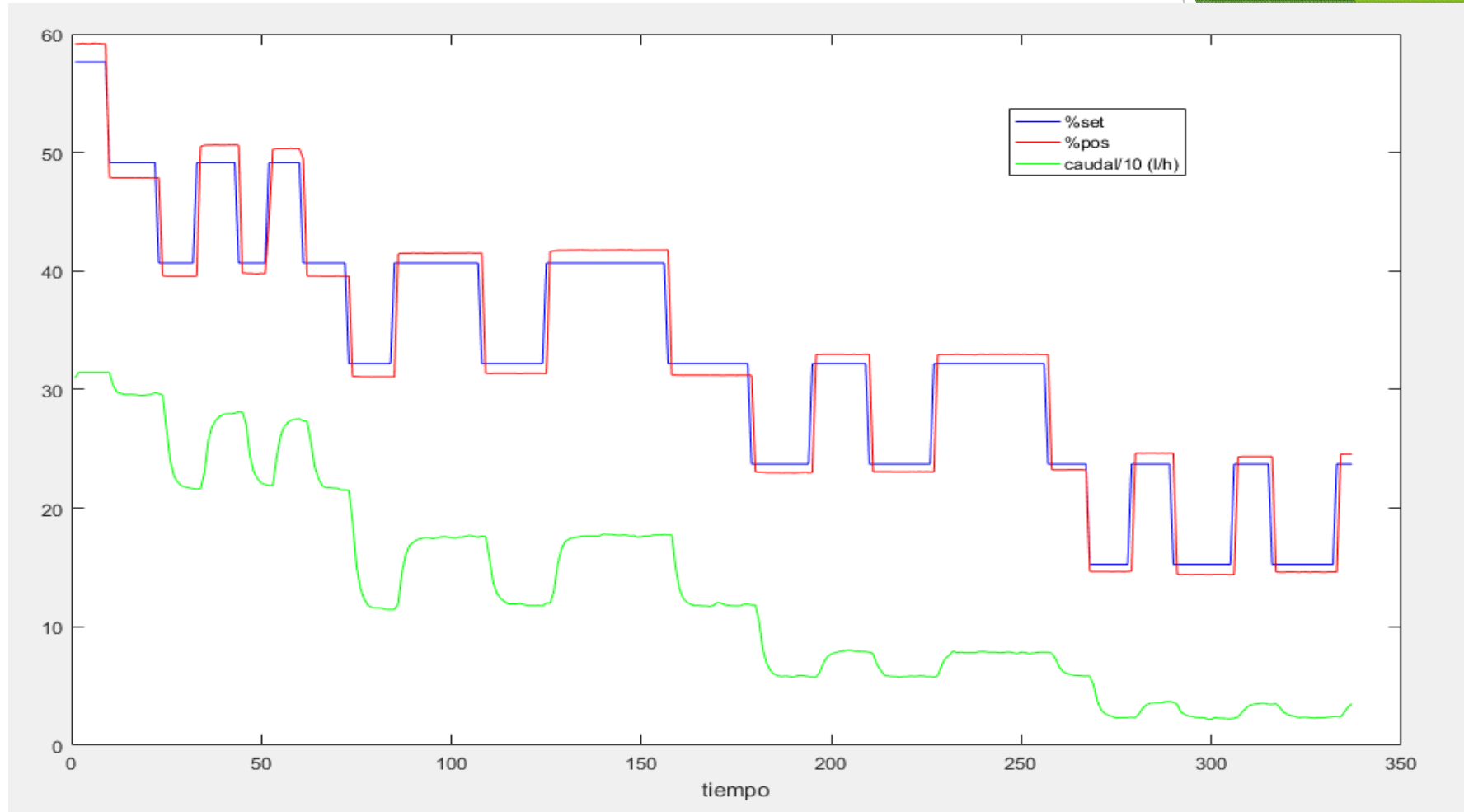
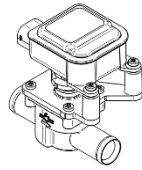


# La válvula

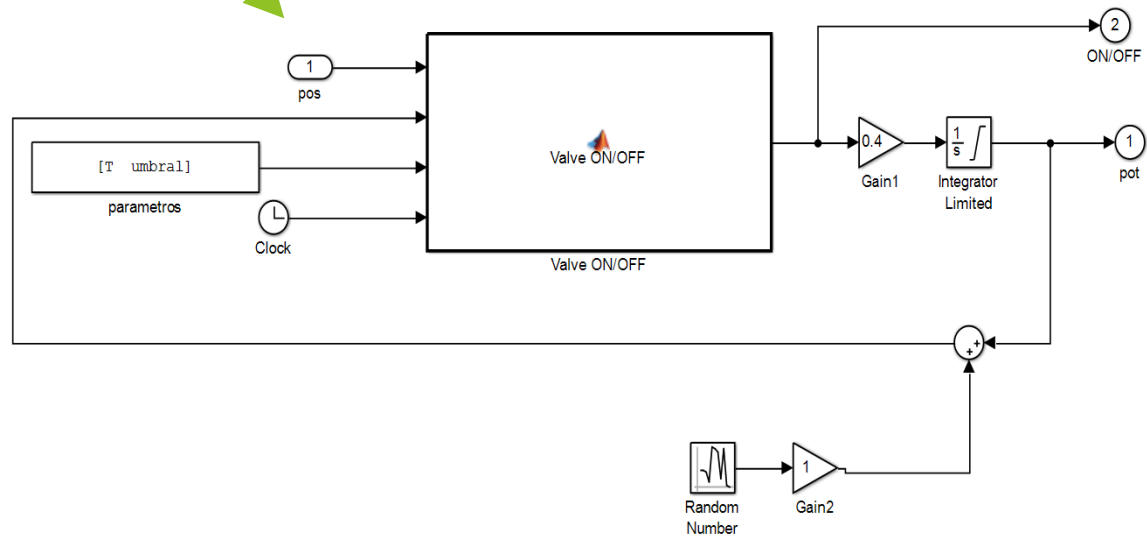
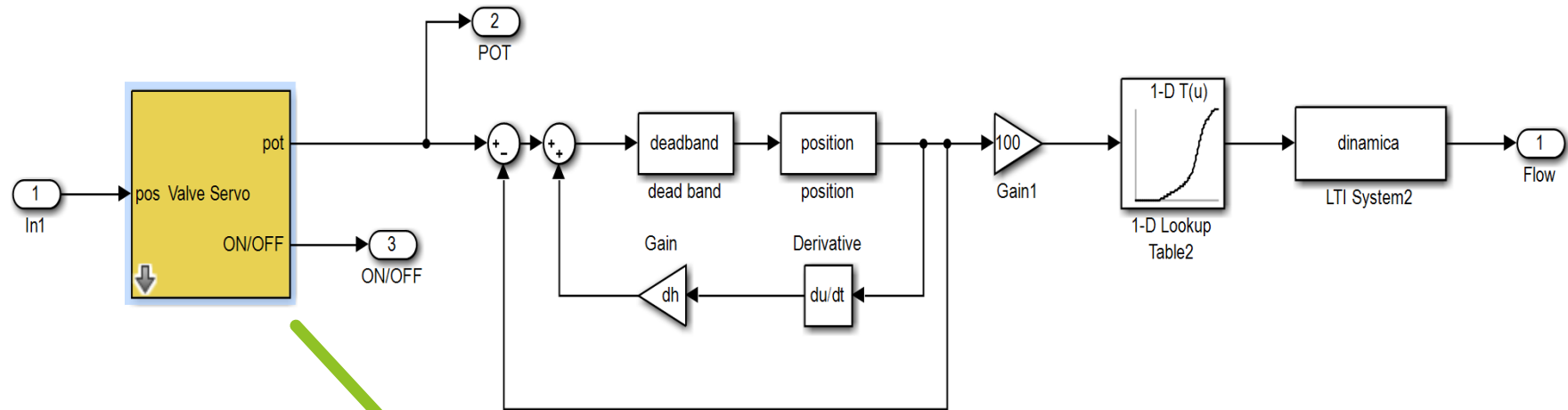
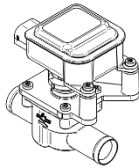


Salto en torno a	40%	30 %	25 %	15 %
Ganancia	0.093	0.089	0.030	0.020

# La válvula



# La válvula



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# Válvula en LC: el PID

$$u(t) = K_p \left( e(t) + \frac{1}{T_i} \int e(t) dt + T_d \frac{d e(t)}{dt} \right)$$

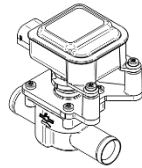
$$e(k) = r(k) - y(k)$$

$$p(k) = K_p (r(k) - y(k))$$

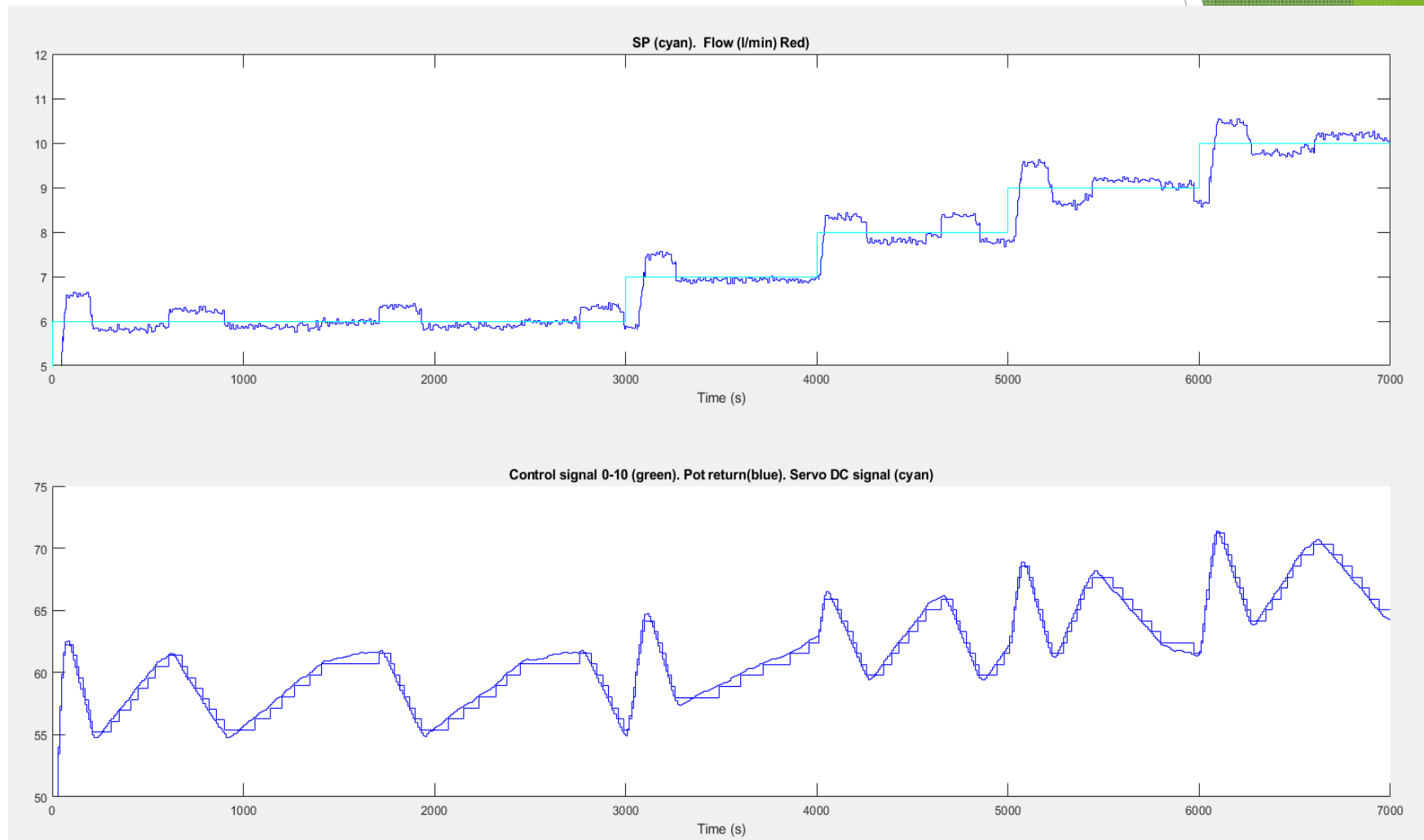
$$i(k) = i(k-1) + \frac{K_p T}{T_i} \frac{e(k) + e(k-1)}{2}$$

$$u(k) = p(k) + i(k)$$

# La válvula

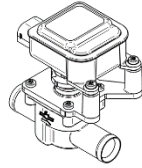


## Respuesta con PI estándar

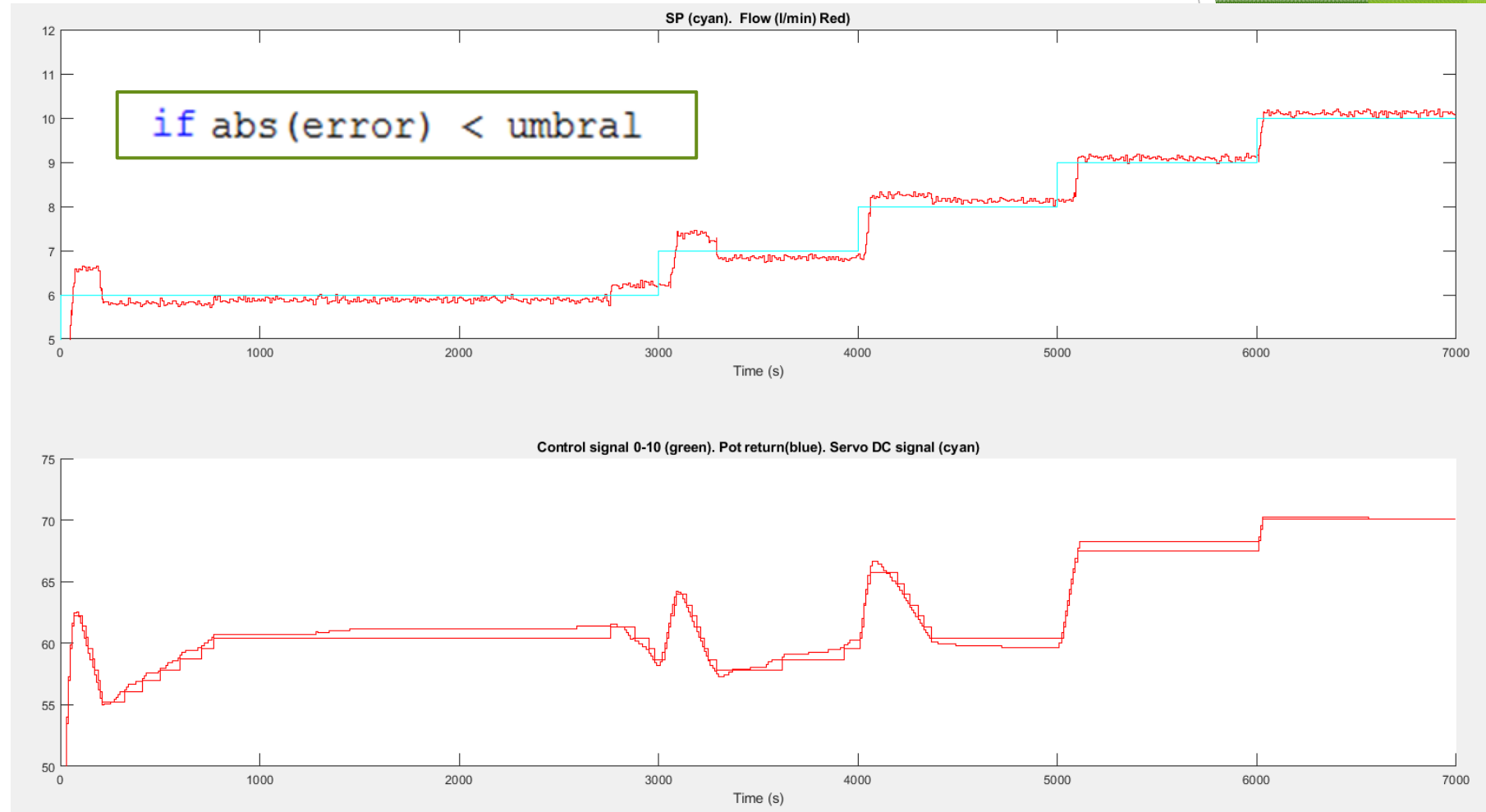




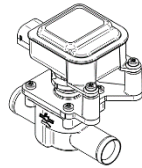
# La válvula



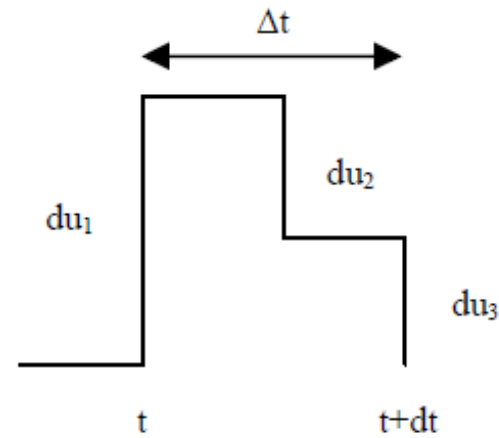
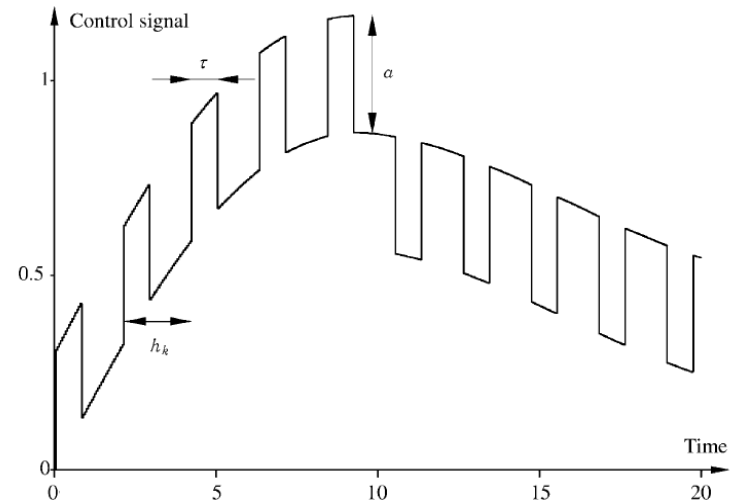
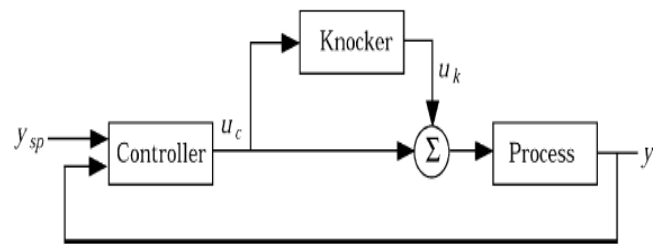
## Añadiendo histéresis al PID



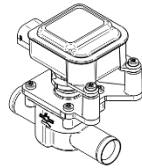
# La válvula



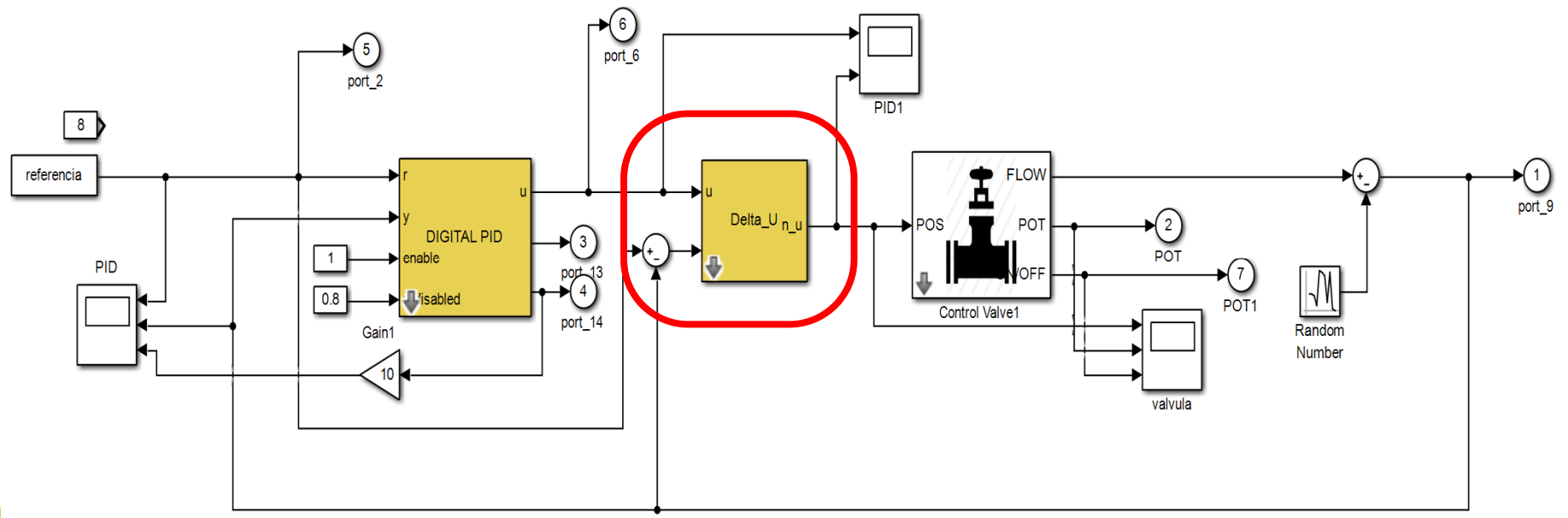
## Añadiendo impulsos al PID



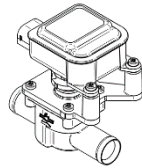
# La válvula



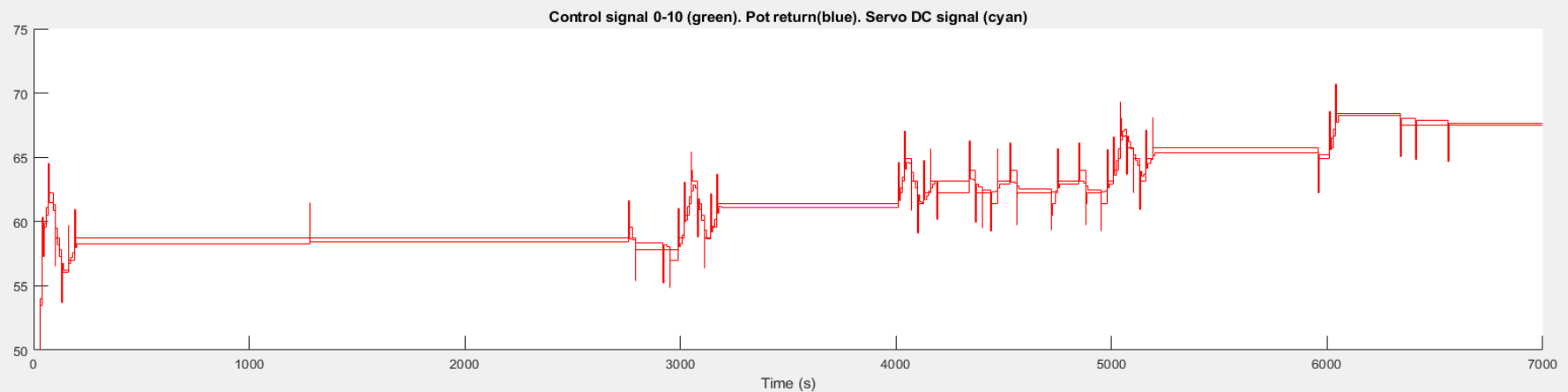
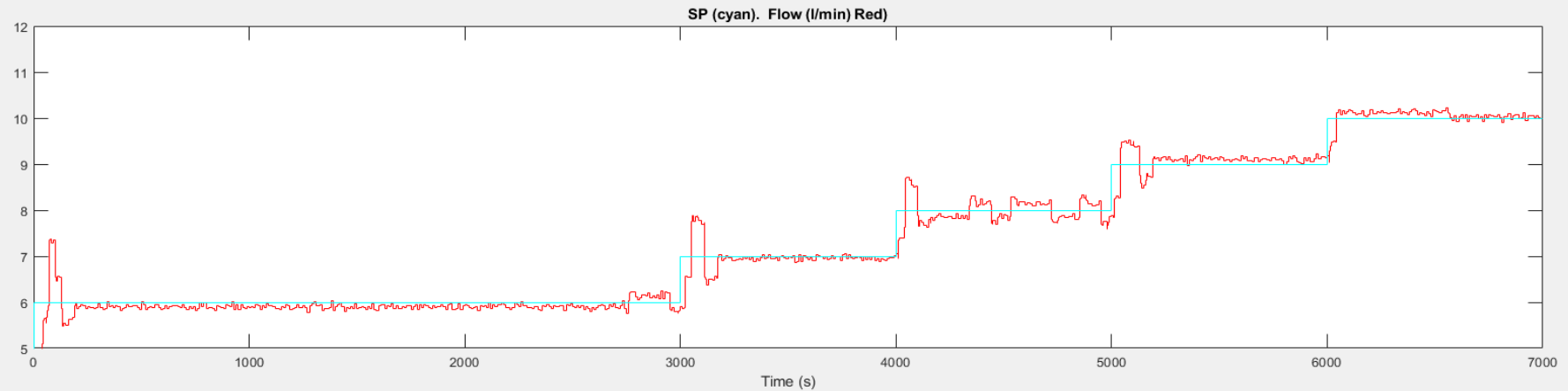
Añadiendo generador de impulsos



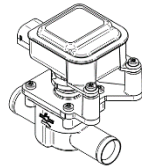
# La válvula



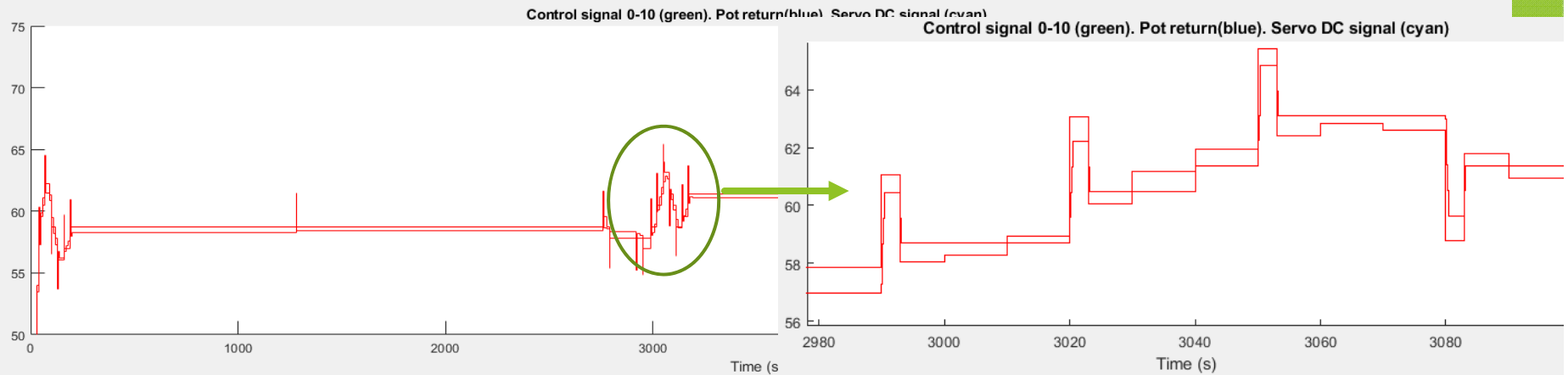
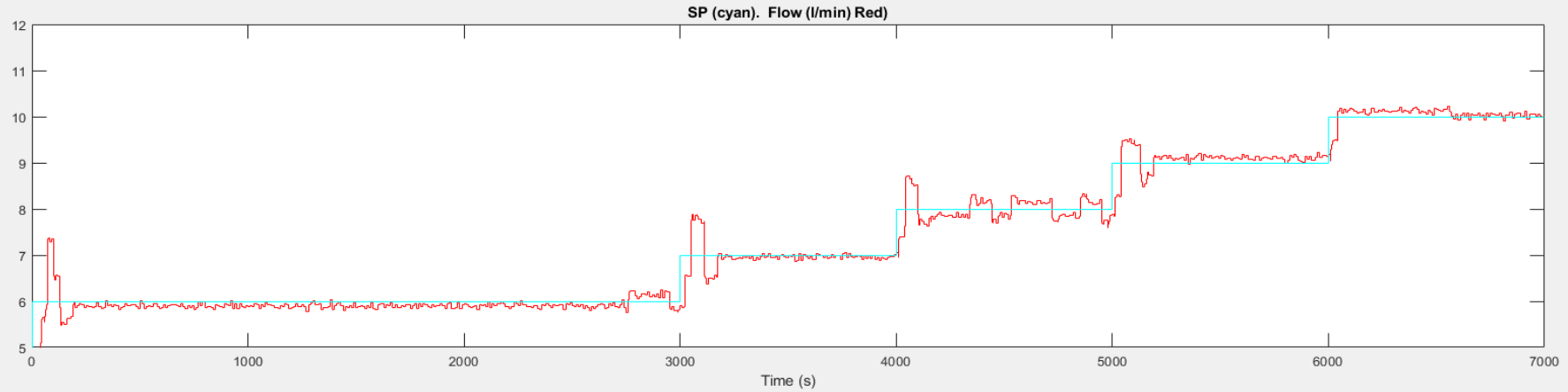
## Añadiendo generador de impulsos



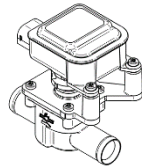
# La válvula



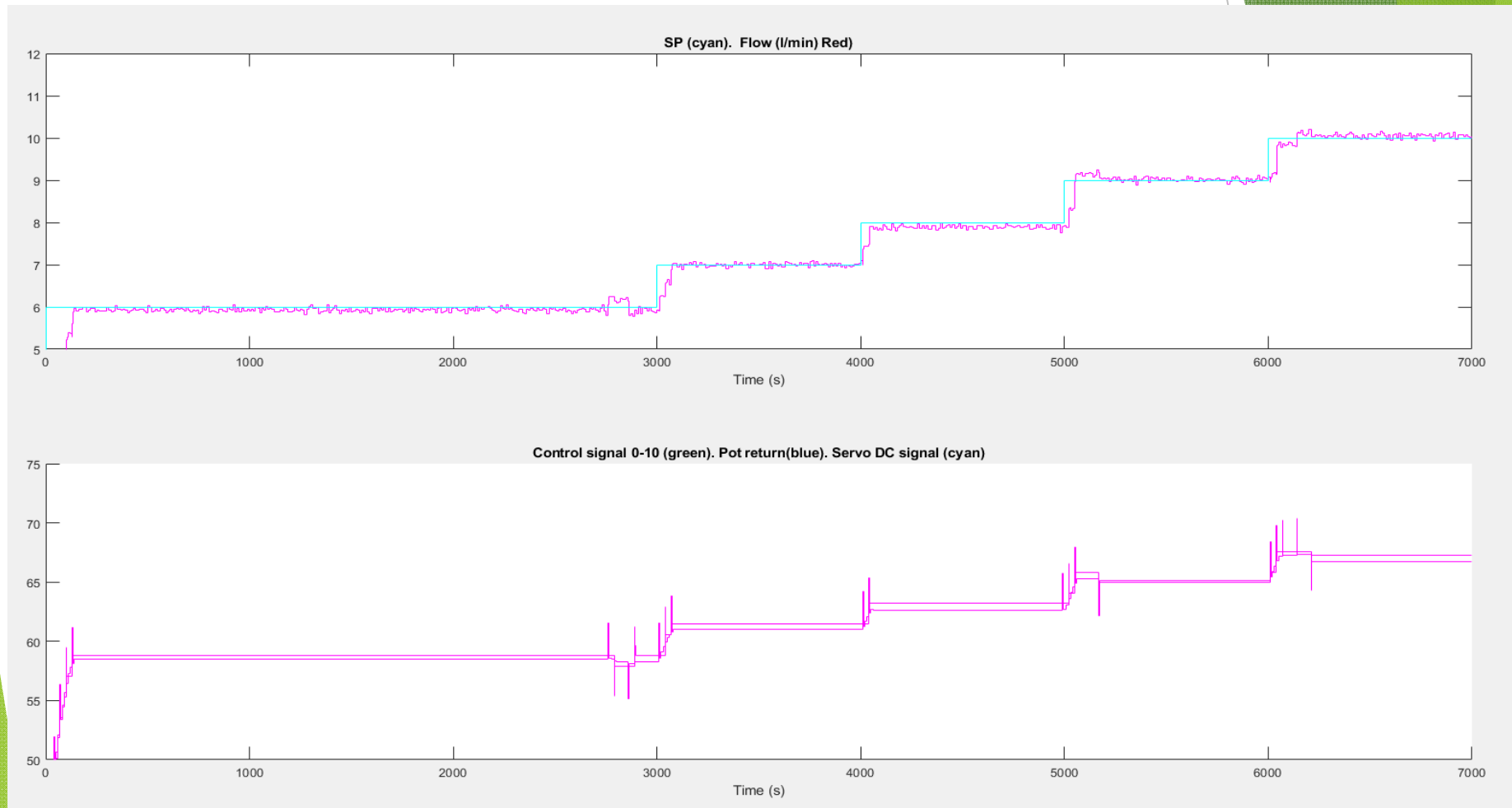
## Añadiendo generador de impulsos



# La válvula



Añadiendo generador de impulsos + resintonía

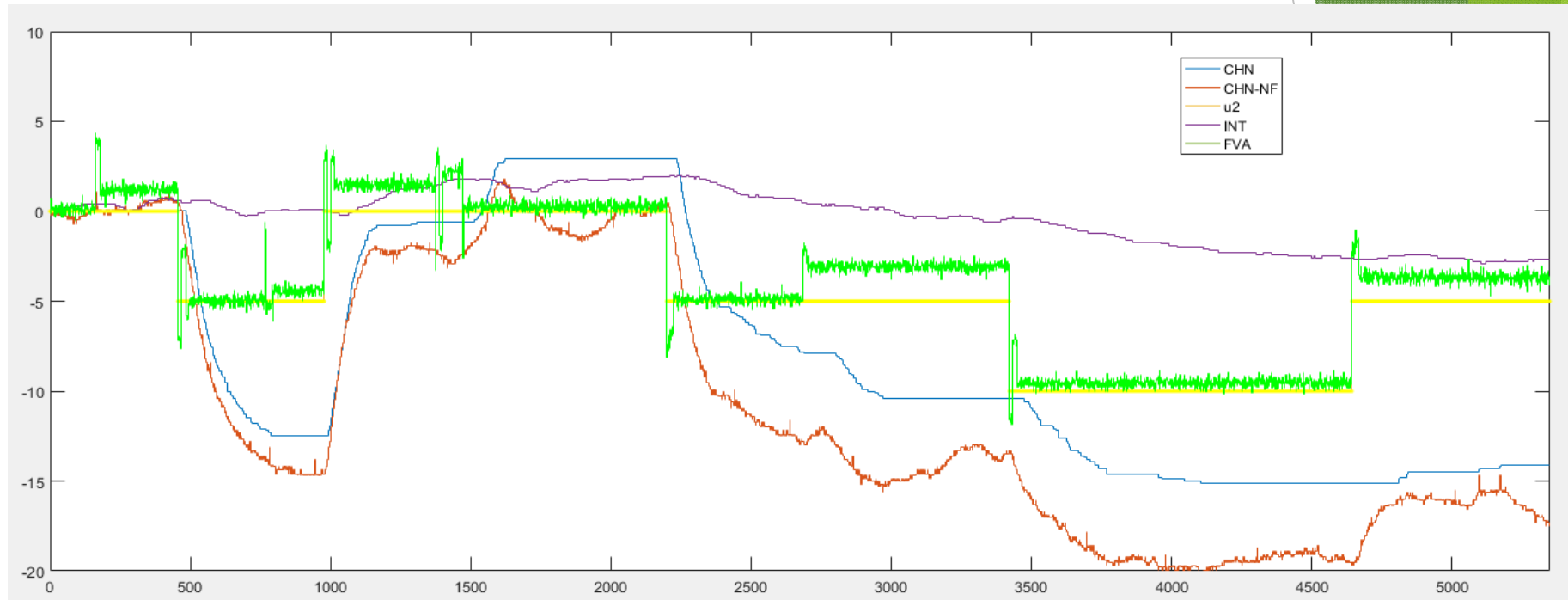


# INDICE

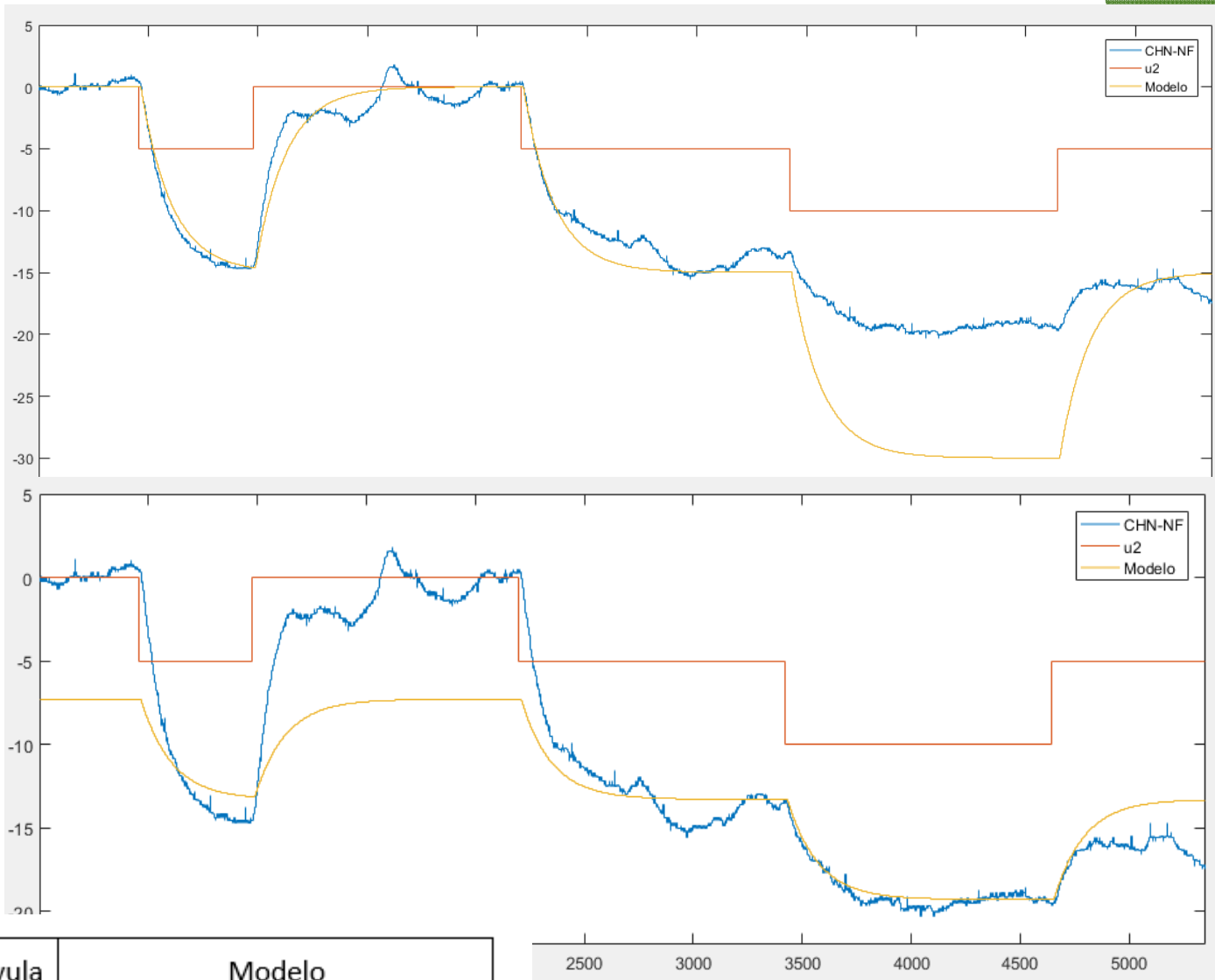
- ▶ Presentación del Grupo
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- ▶ **Ensayos a bordo**
- ▶ Trabajo actual



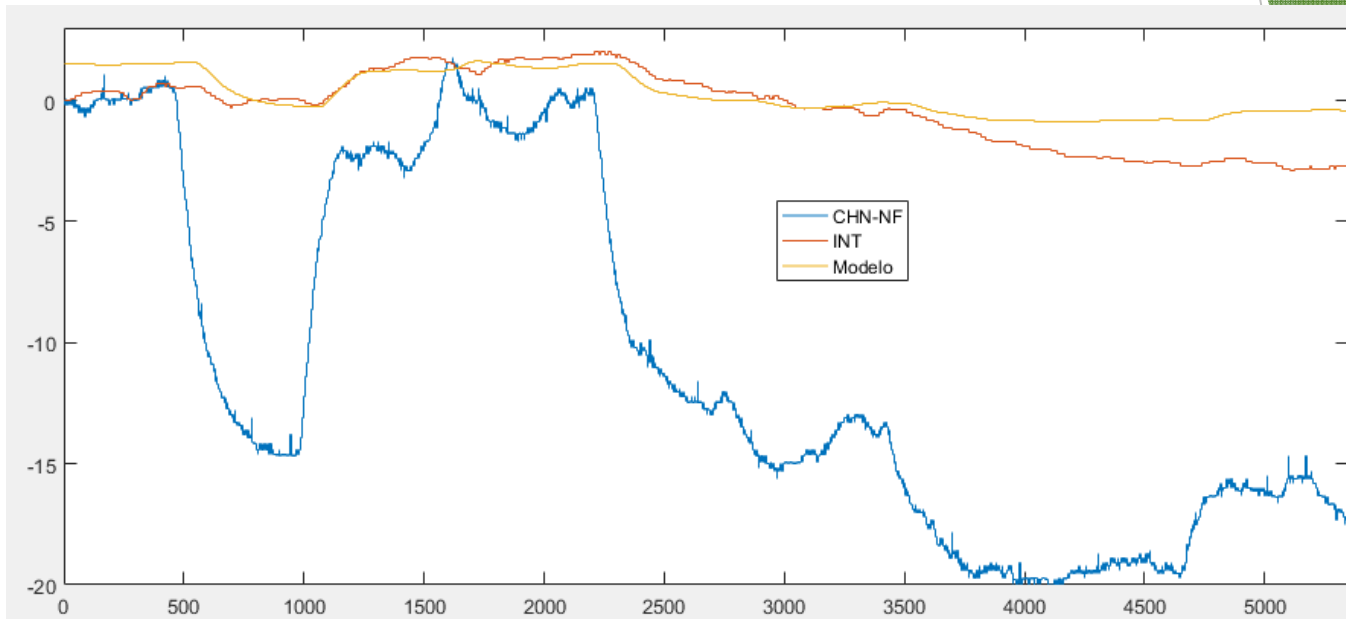
# Pruebas a bordo: LA



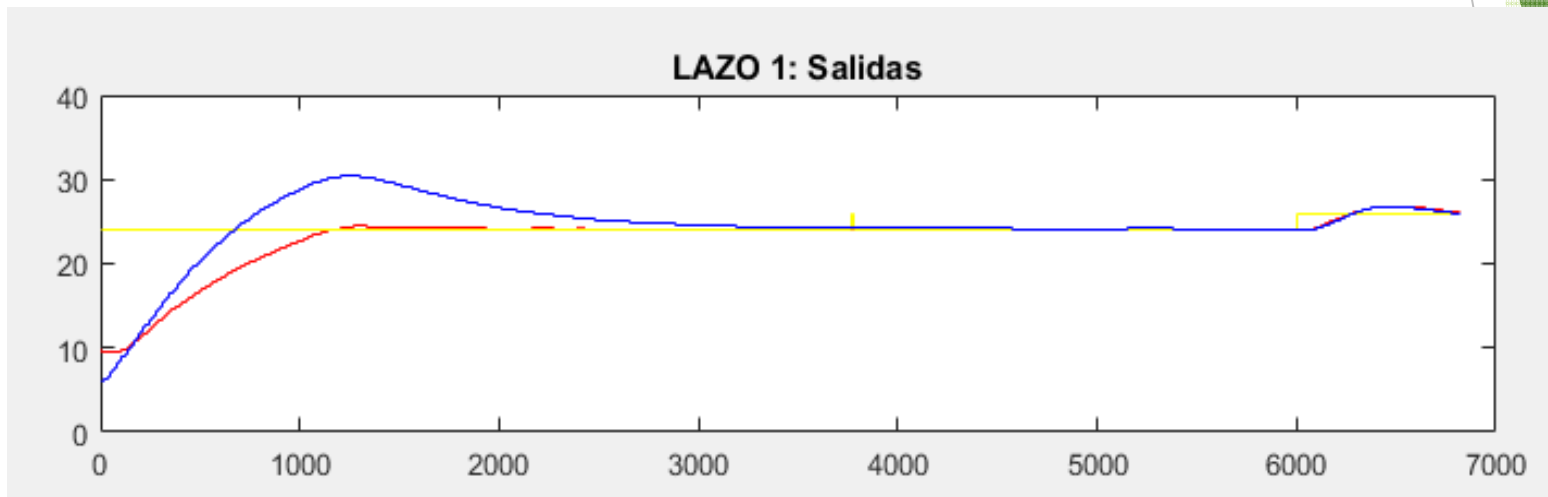
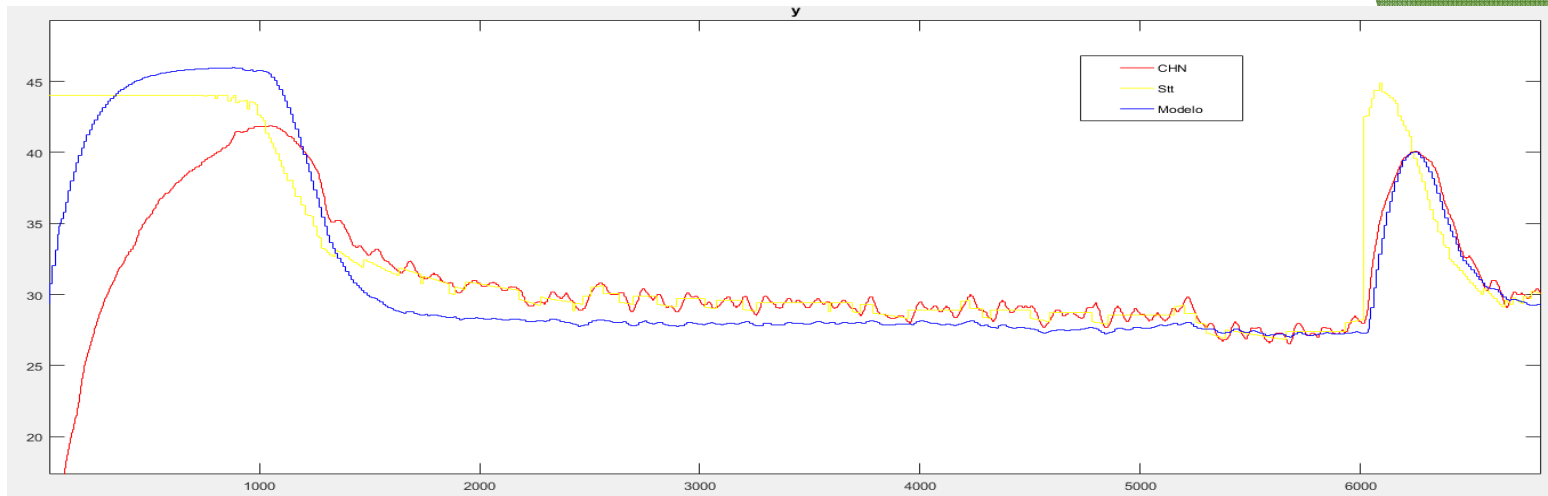




Válvula	Modelo
%40	$GC2(s) = \frac{300}{140s + 1} e^{-10s}$
%25	$GC2(s) = \frac{130}{140s + 1} e^{-10s}$



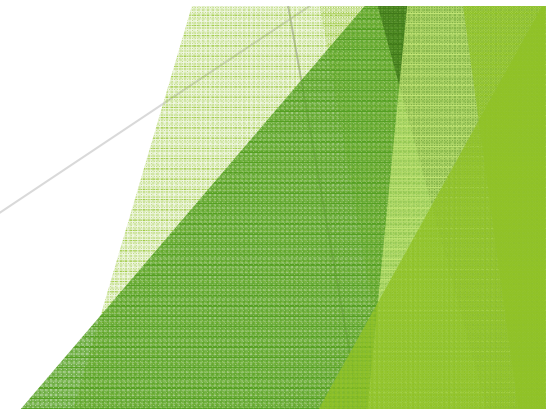
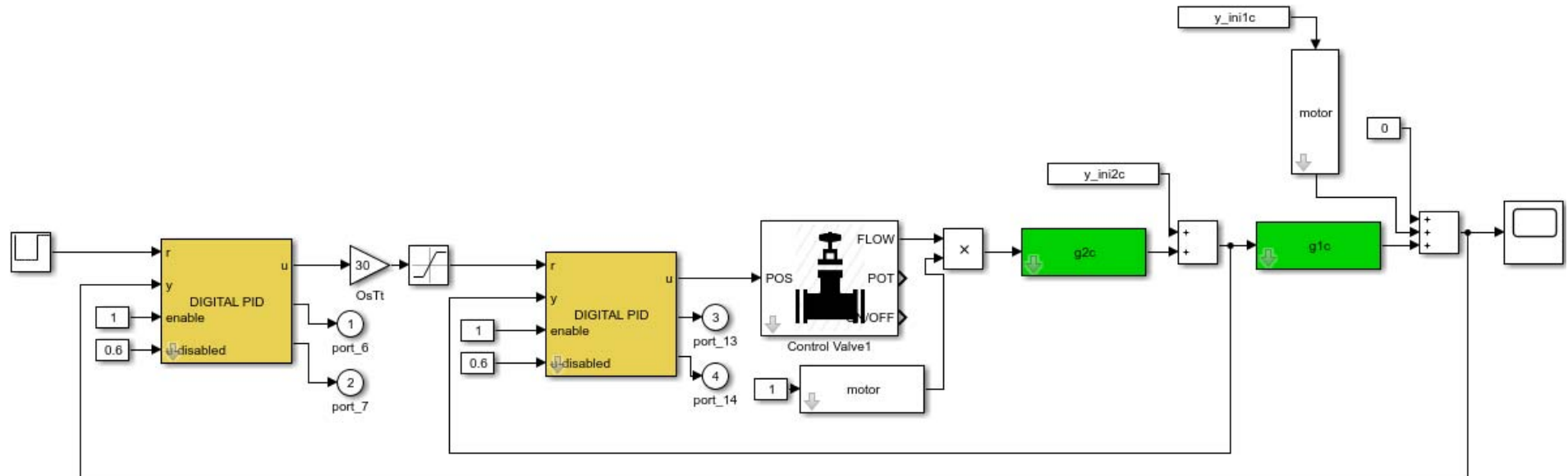
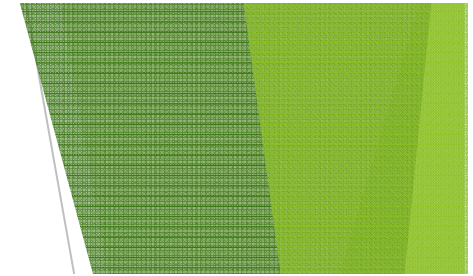
$$GC1(s) = \frac{0.12}{35s + 1} e^{-80s}$$



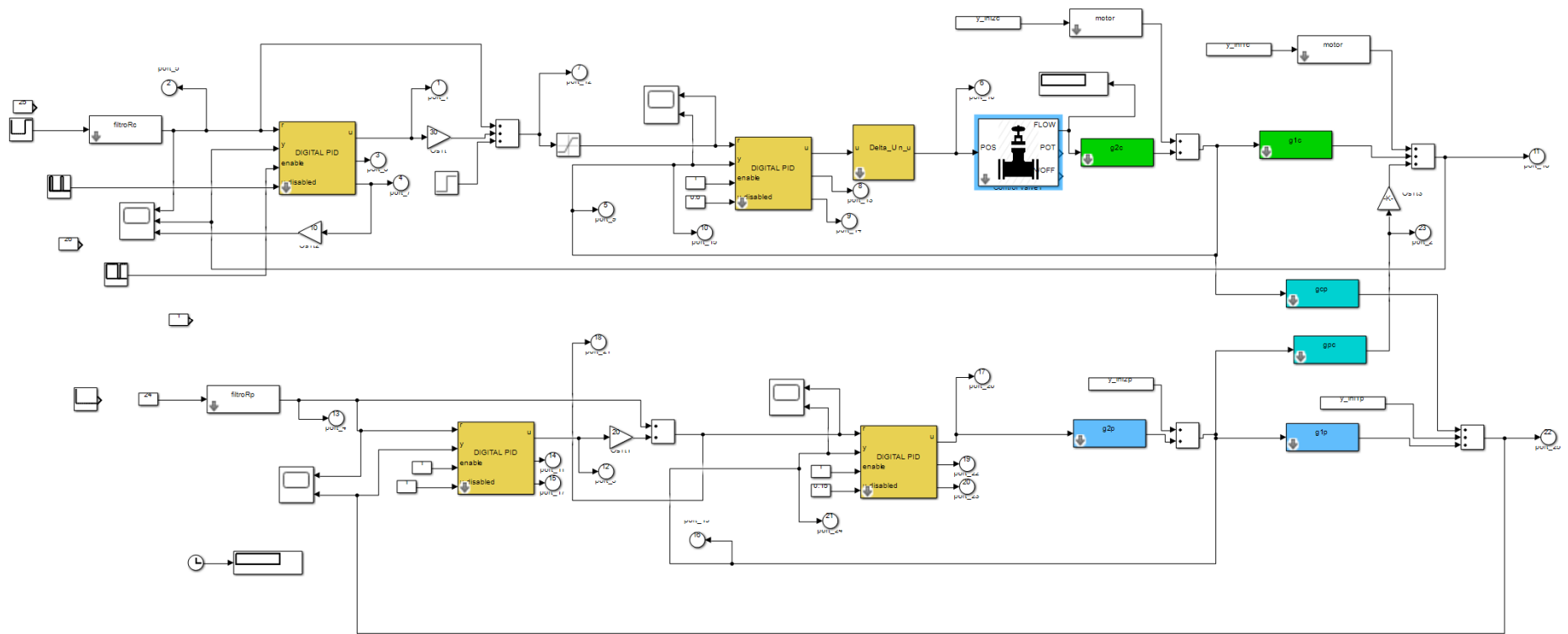
$$GP1(s) = \frac{0.64}{635s + 1} e^{-10s}$$

$$GP2(s) = \frac{20}{140s + 1} e^{-10s}$$

# Pruebas a bordo: modelo



# Pruebas a bordo: modelo

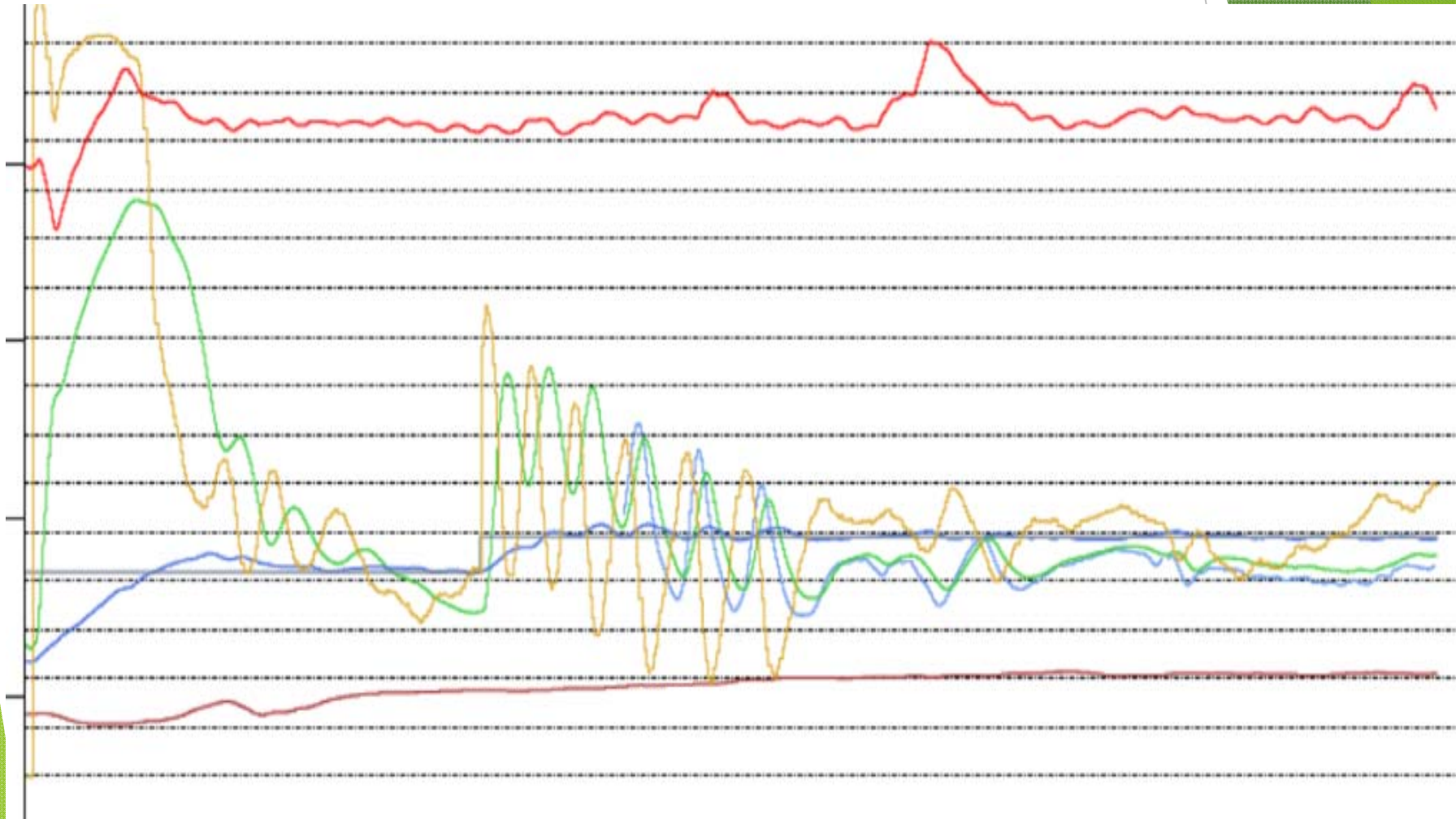


# Pruebas a bordo: interacción



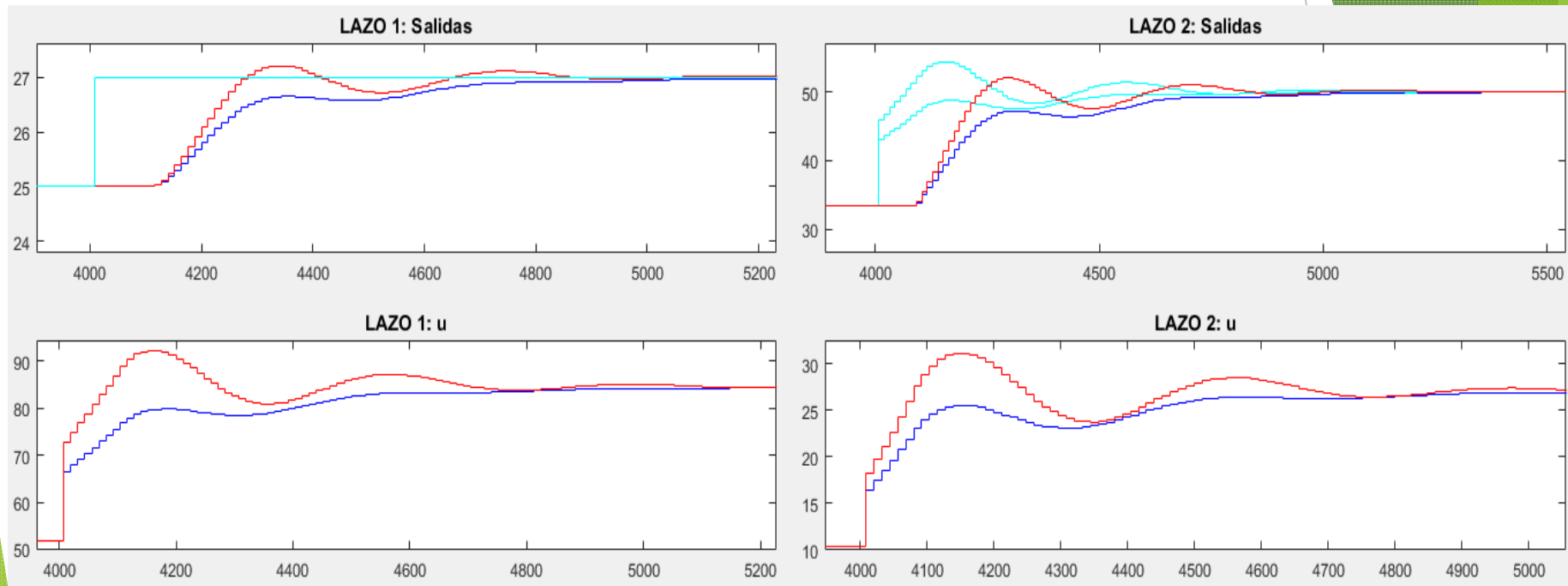
# Pruebas a bordo

- Problemas por mala sintonía de parámetros



# Pruebas a bordo

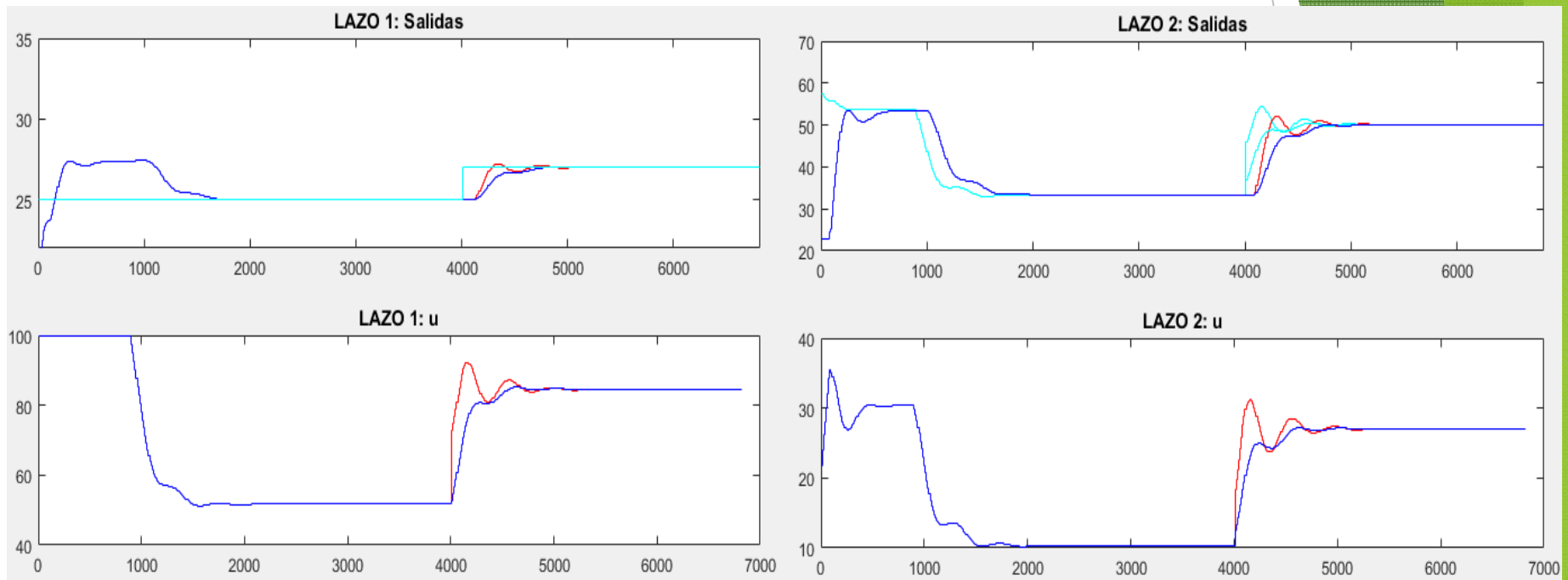
- ▶ Mejoras: reajuste de parámetros





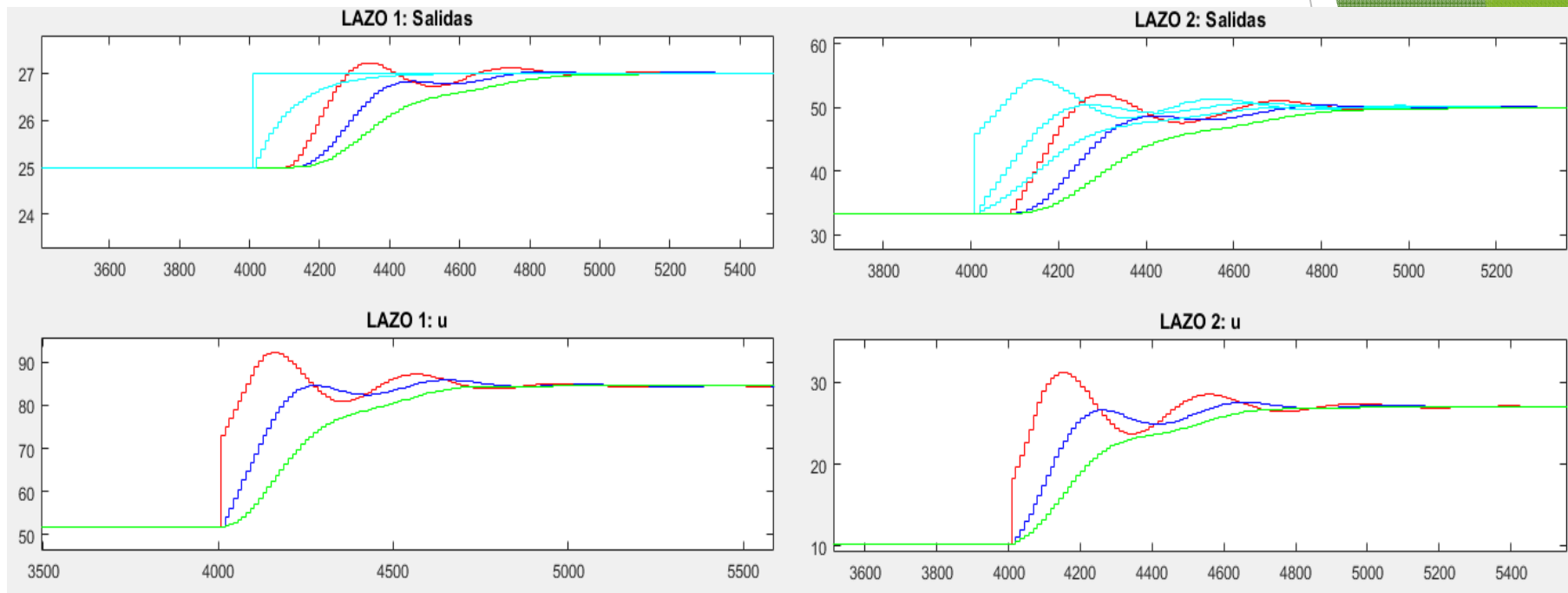
# Pruebas a bordo

- ▶ Mejoras por cambio en el set-point ( $b=0$ )



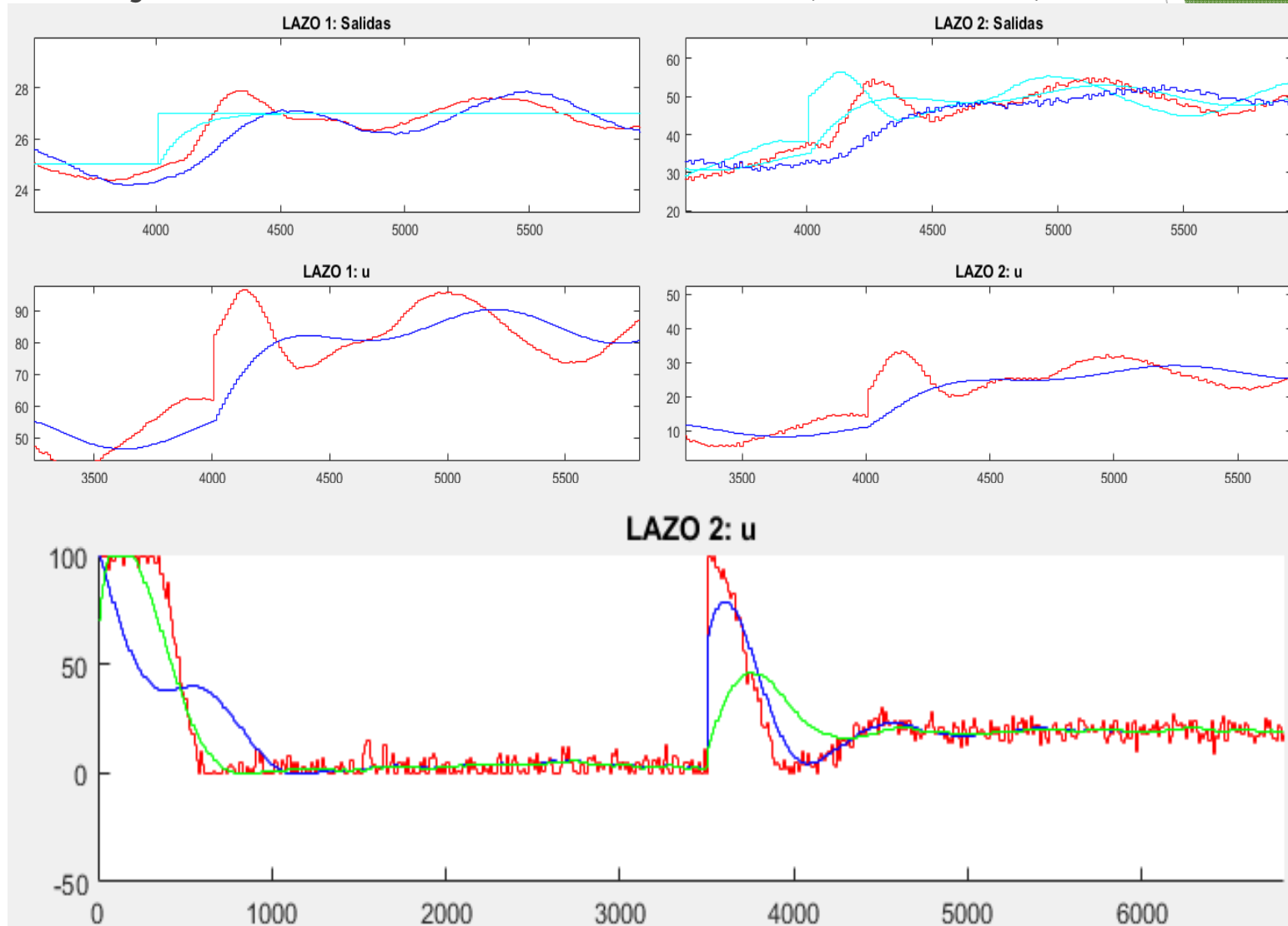
# Pruebas a bordo

- Mejoras por cambio en el set-point (filtrado)



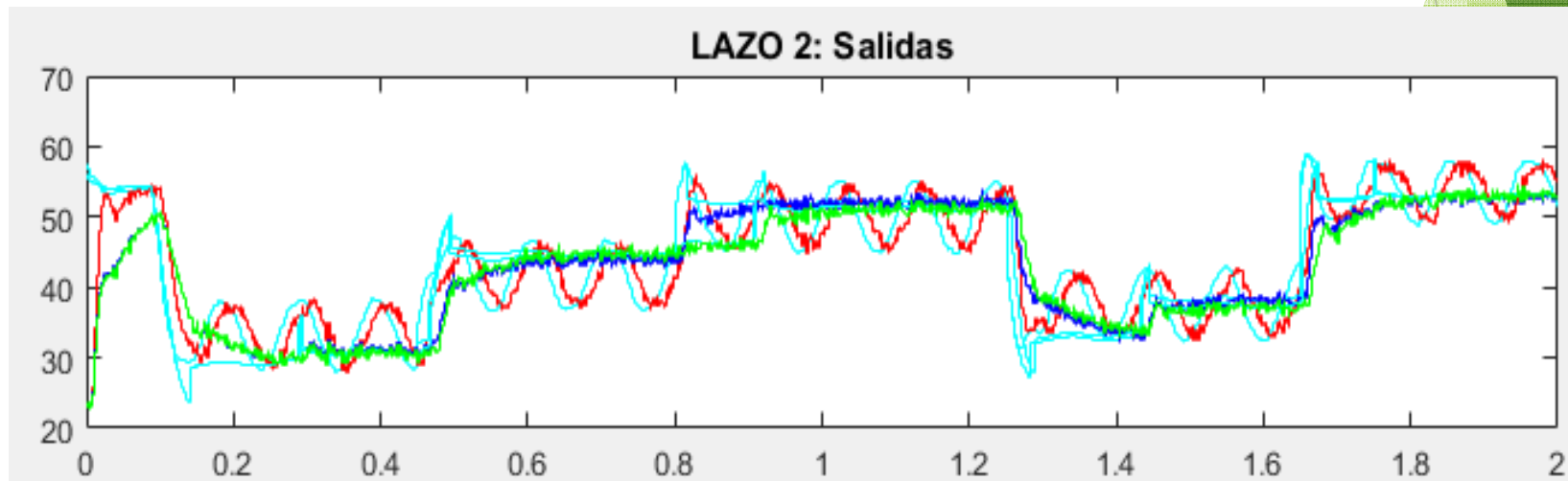
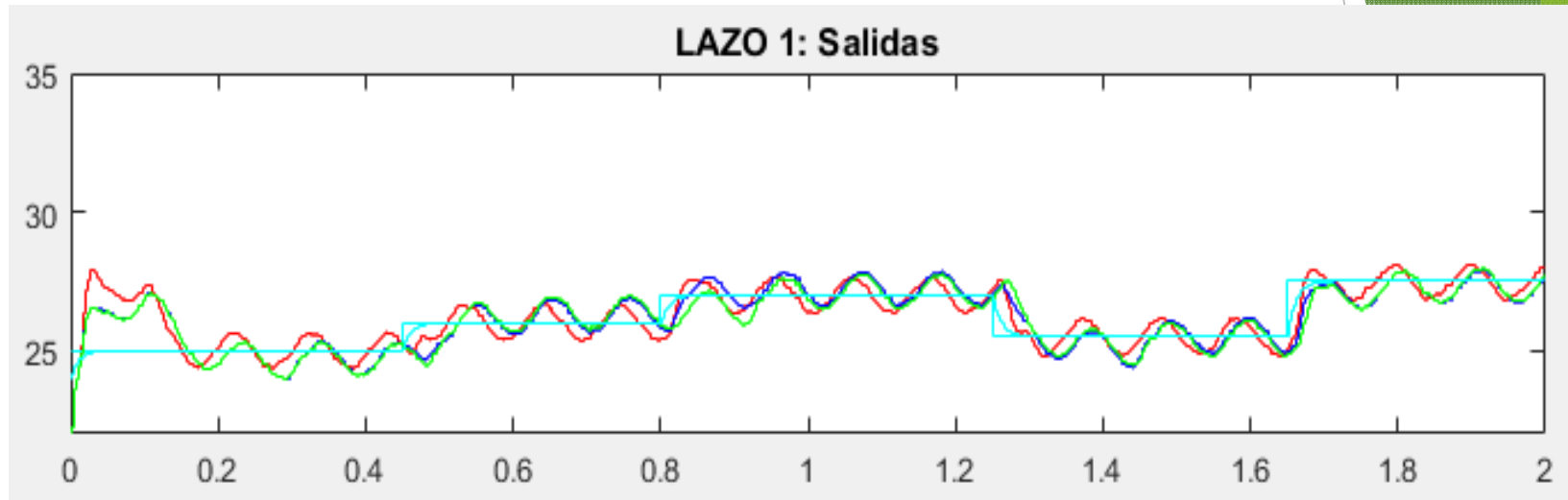
# Pruebas a bordo

- ▶ Mejora de la medida señales con filtros (Butterworth)

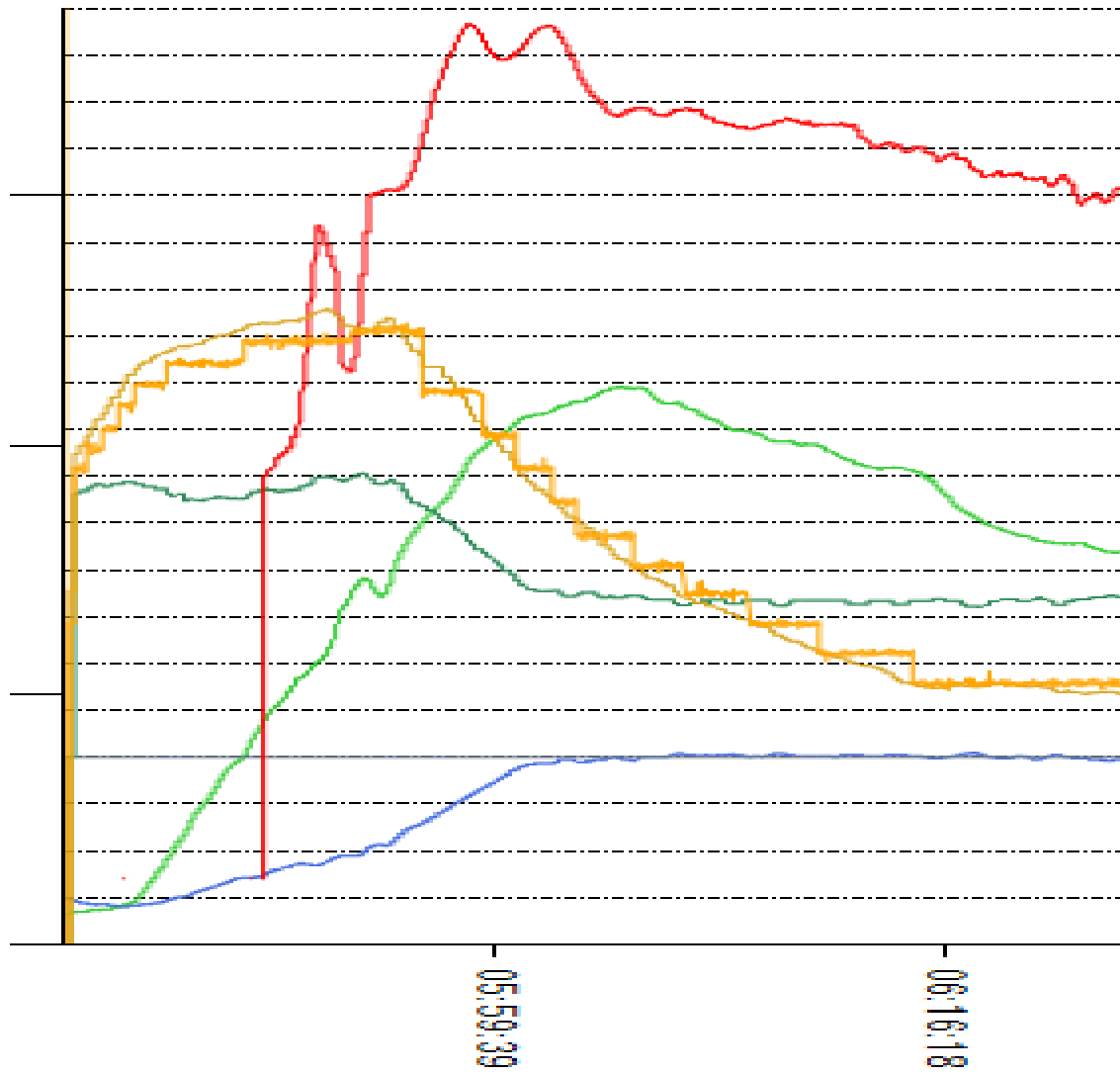


# Pruebas a bordo

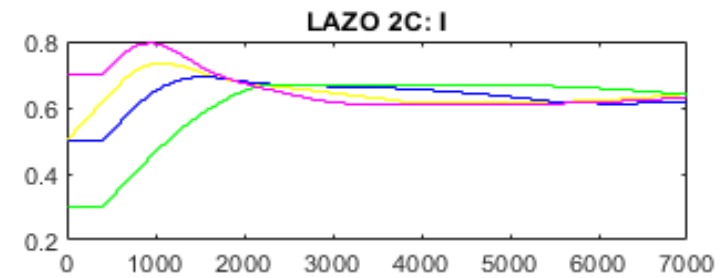
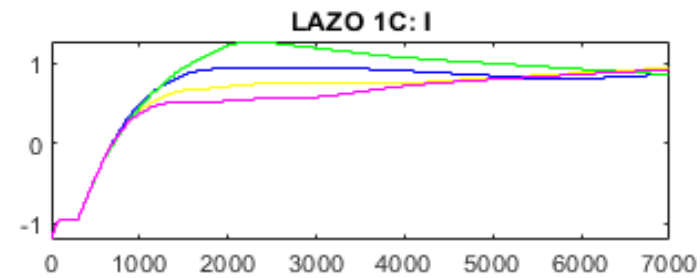
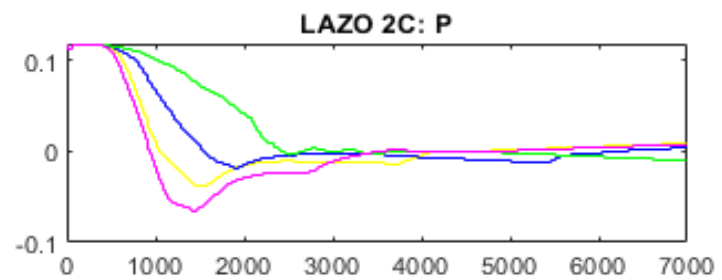
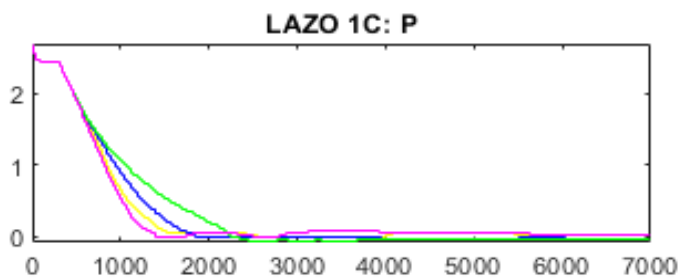
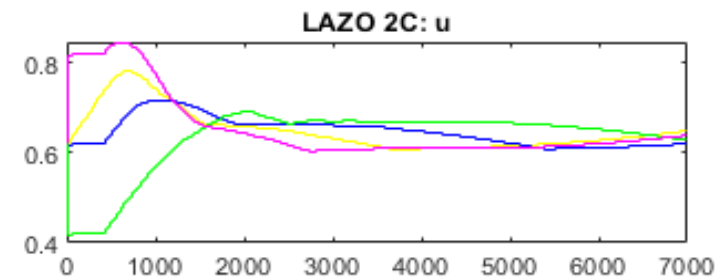
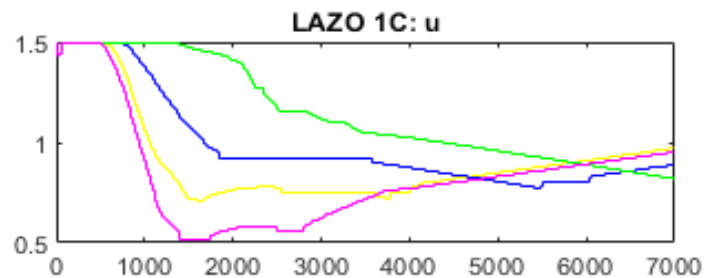
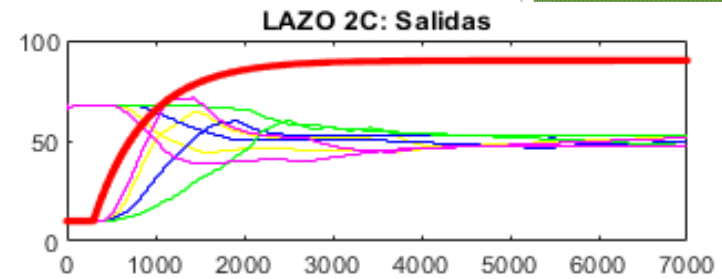
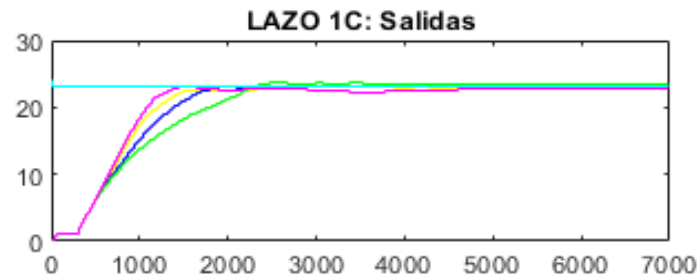
## ► Histéresis



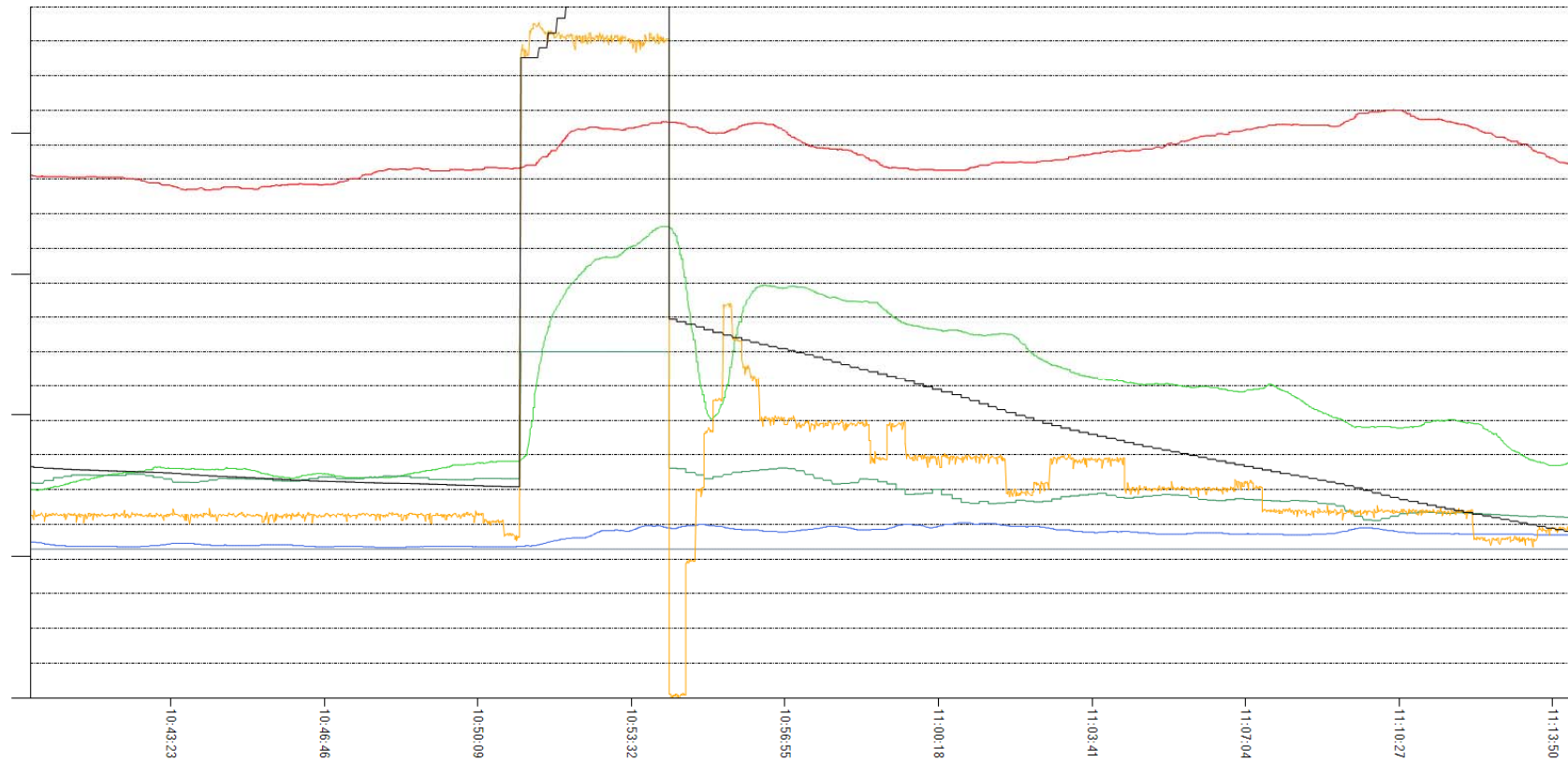
# Pruebas a bordo: inicialización



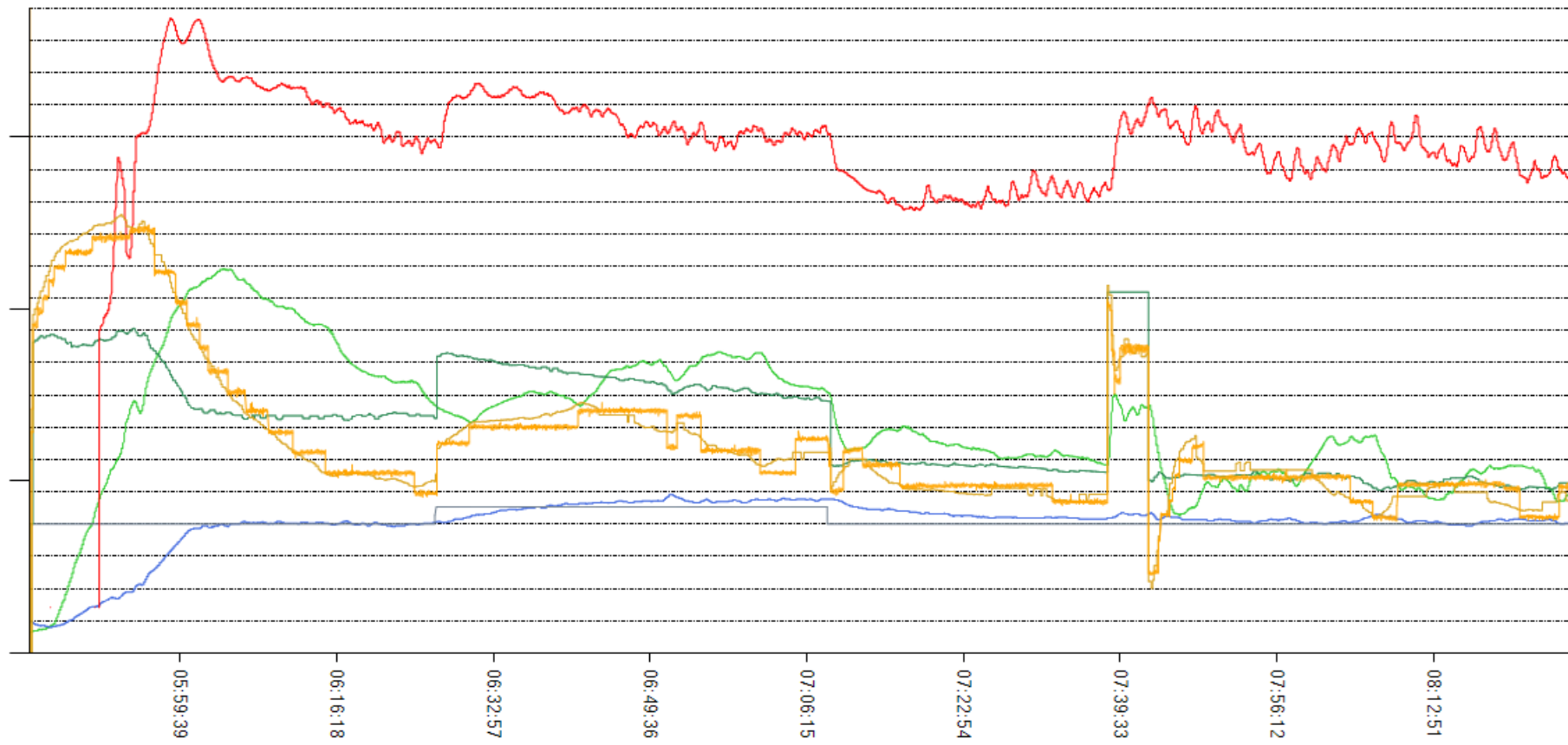
# Pruebas a bordo: inicialización



# Pruebas a bordo

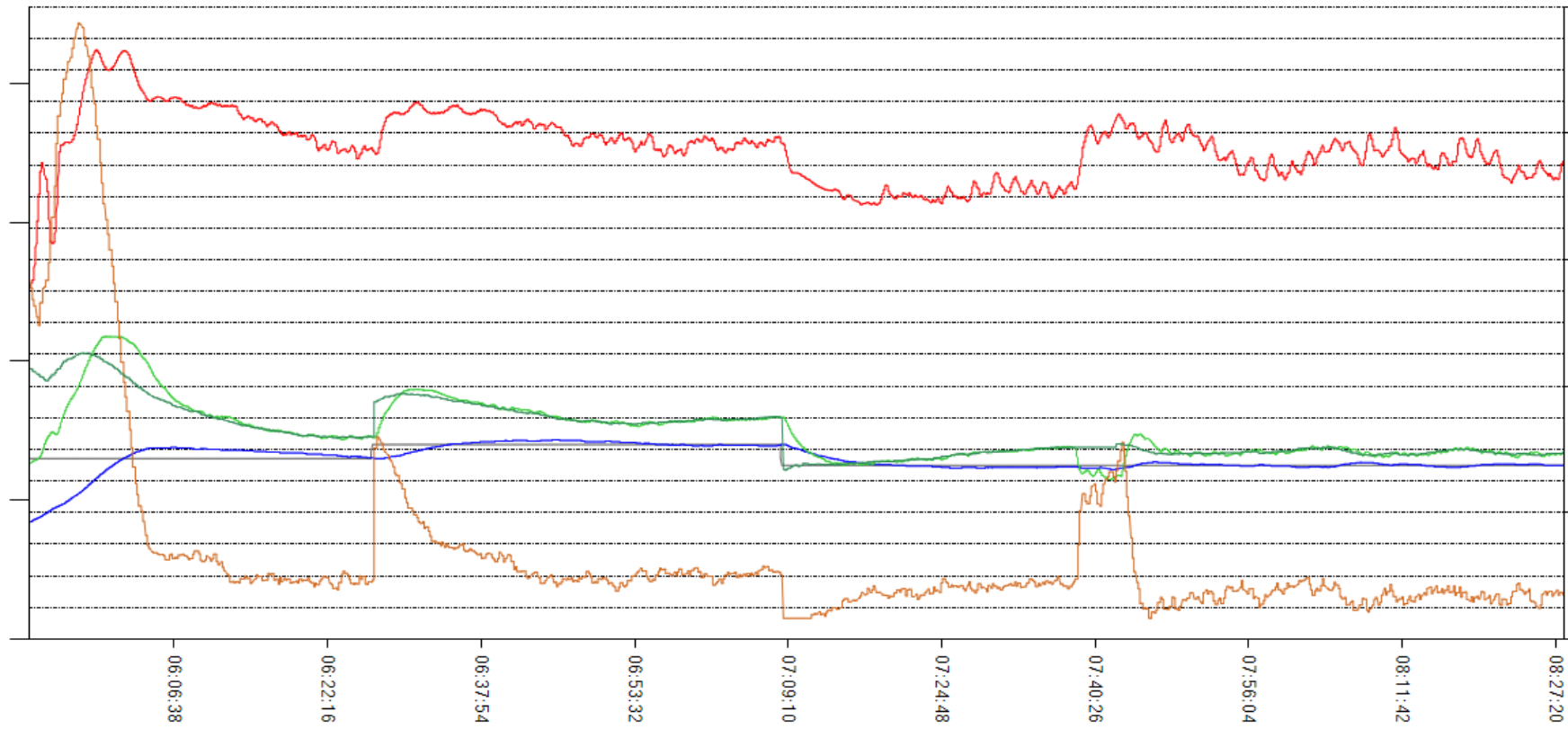


# Pruebas a bordo: lazo conductor



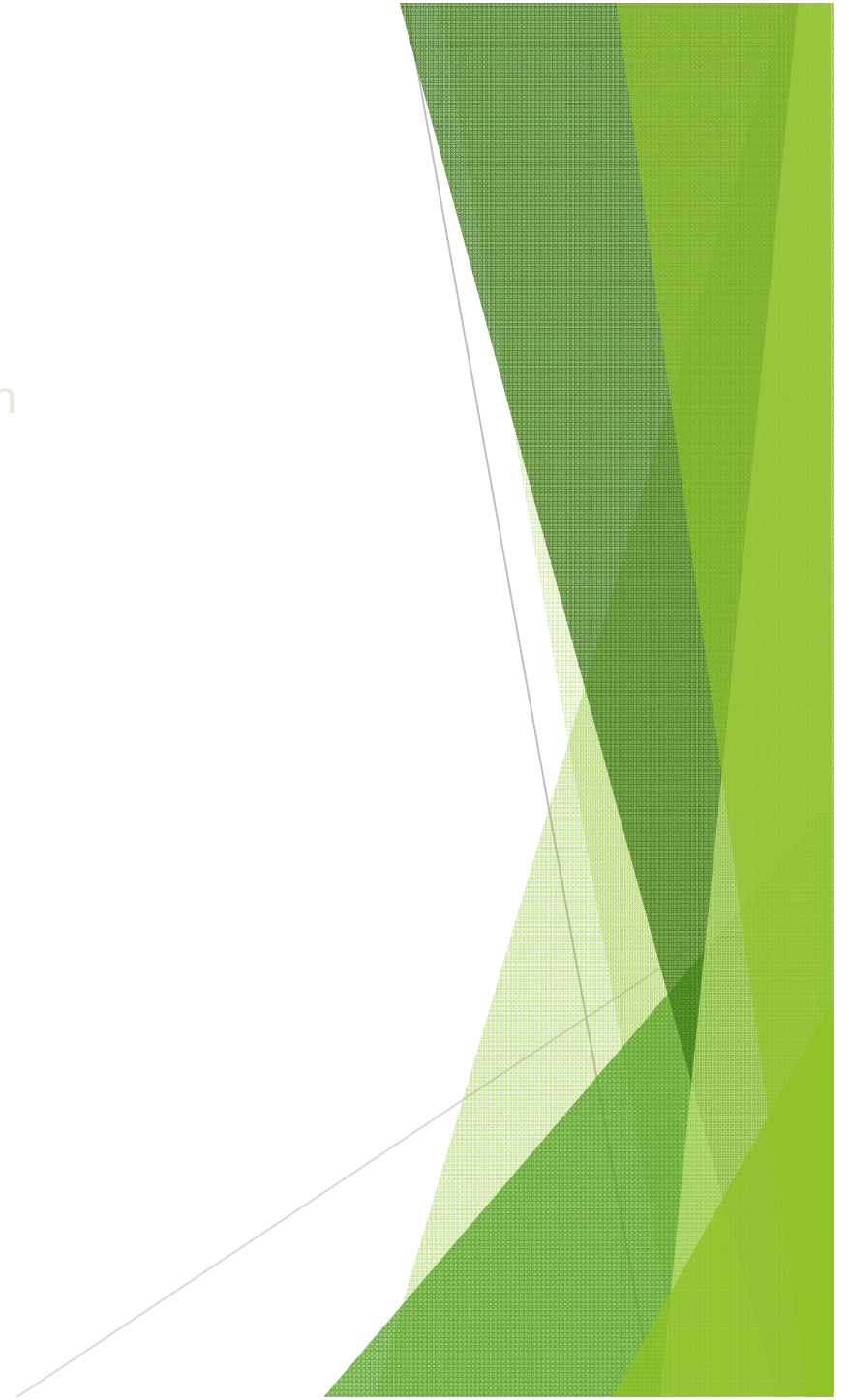
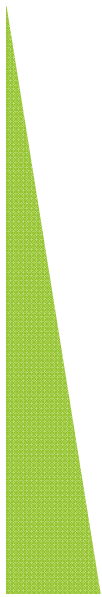


# Pruebas a bordo: lazo pasajeros



# INDICE

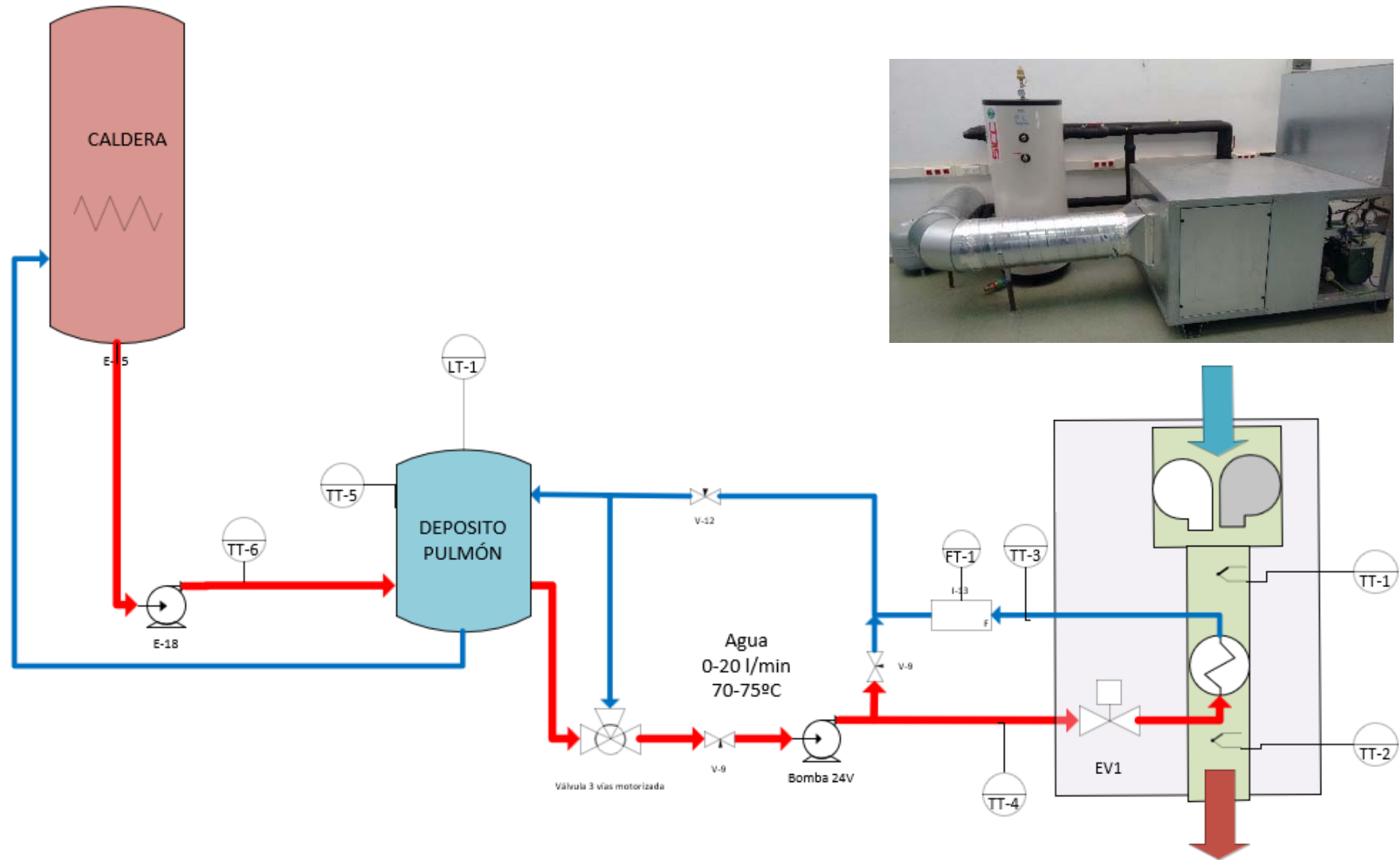
- ▶ Presentación del Grupo
- ▶ Introducción
- ▶ Componentes del sistema de calefacción
- ▶ La válvula de control
- ▶ Ensayos a bordo
- ▶ Trabajo actual



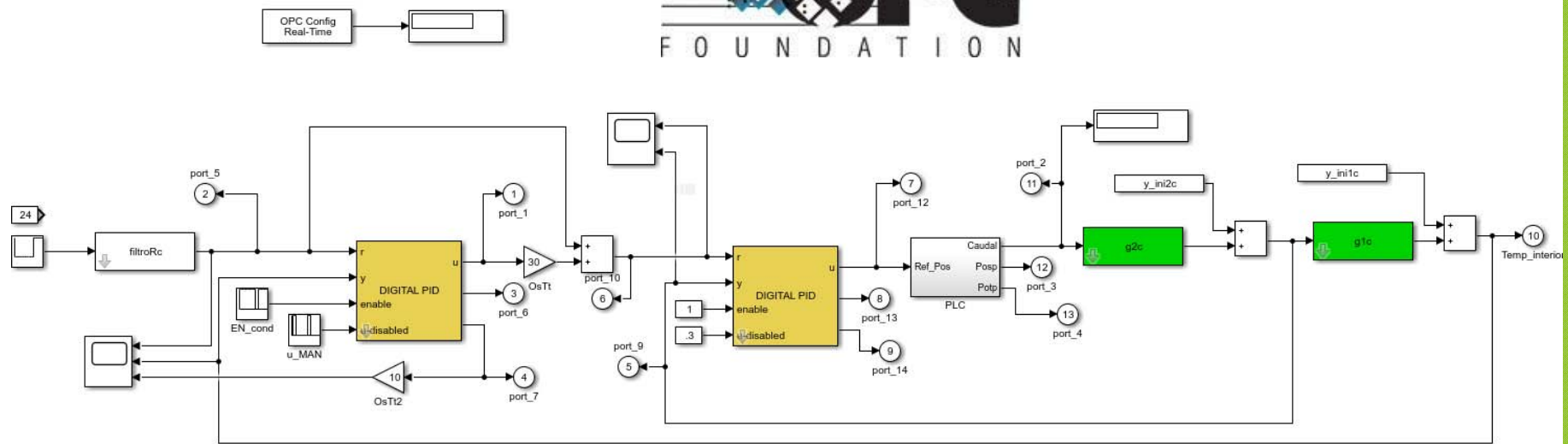
# Trabajo actual



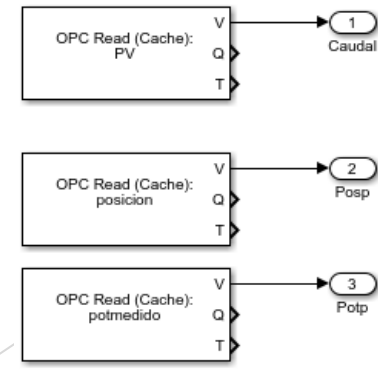
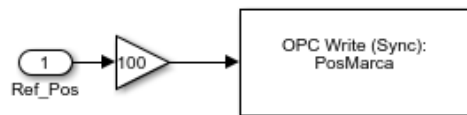
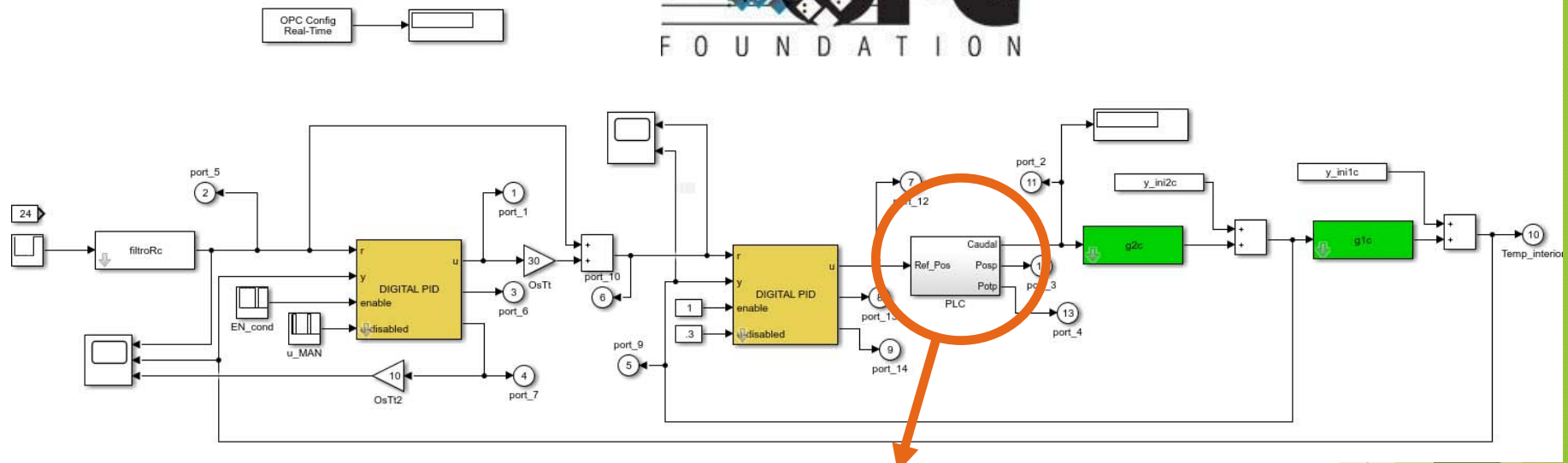
# Trabajo actual



# Trabajo actual: Ensayos híbridos



# Trabajo actual: Ensayos híbridos



# Agradecimientos

- ▶ Proyecto P18-TP-2040: Diseño de estrategias de control de calefacción en vehículos de transporte público
  - Modalidad Colaboración Tejido Productivo. 2020-22

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CONOCIMIENTO Y UNIVERSIDADES**

Secretaría General de Universidades, Investigación y Tecnología

