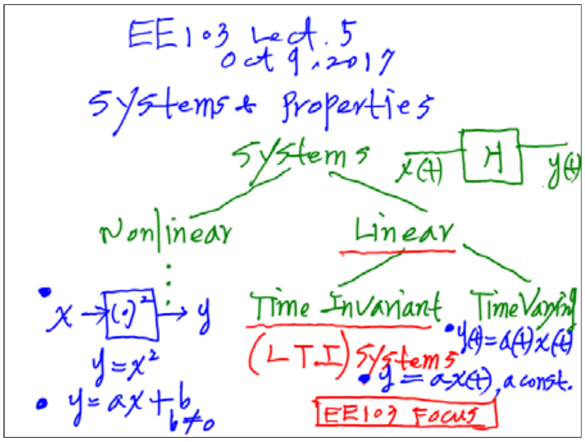
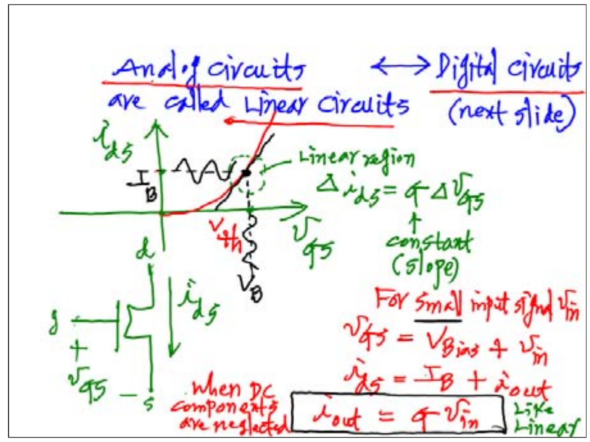
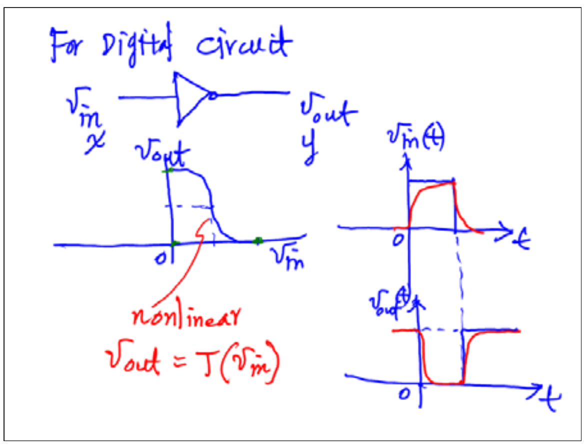
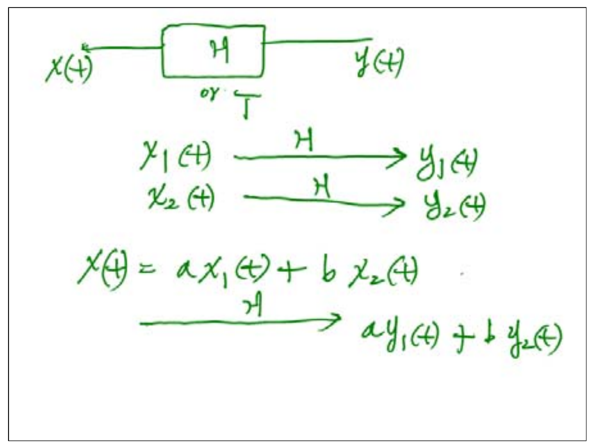
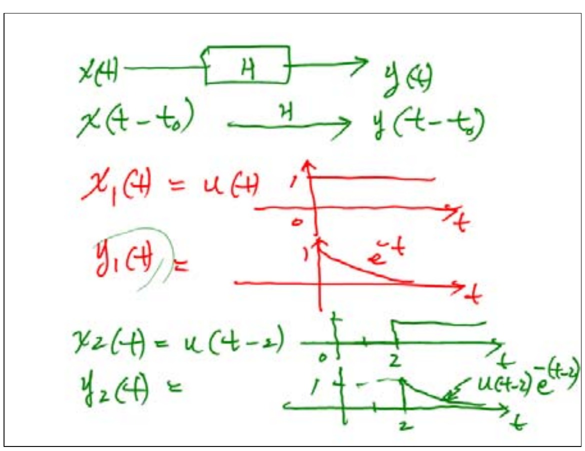
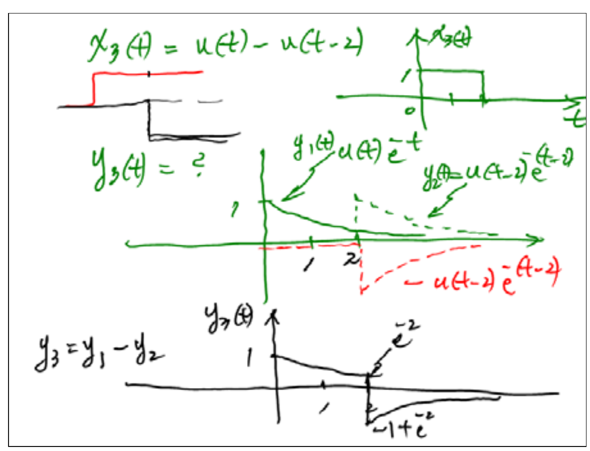

EE103 Lect. 5
Oct 9, 2017
Systems & Properties
Systems
x(t) → H → y(t)
Nonlinear
Linear
x → (·)² → y
y = x²
y = ax + b, b ≠ 0
Time Invariant
(LTI) Systems
Time Varying
y(t) = a(t)x(t)
y = ax(t), a const.
EE103 Focus

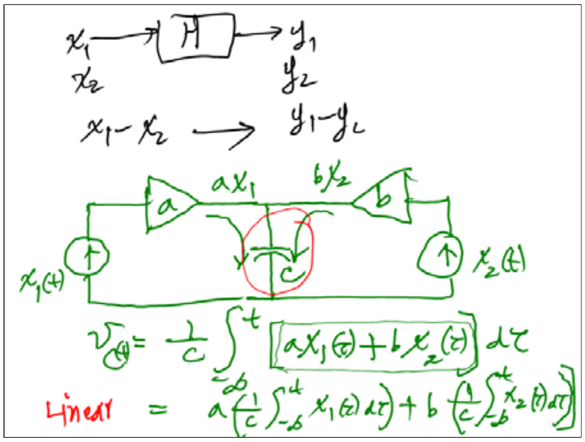

Analog circuits ↔ Digital circuits
are called Linear circuits
(next slide)
Linear region
Δi_ds = g Δv_gs
constant (slope)
For small input signal v_in
v_gs = V_Bias + v_in
i_ds = I_B + i_out
when DC components are neglected
i_out = g v_in
Like Linear

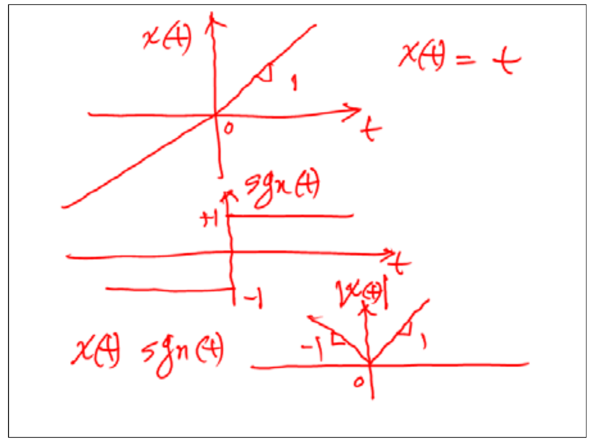

For Digital circuit
v_in
x
v_out
y
nonlinear
v_out = T(v_in)

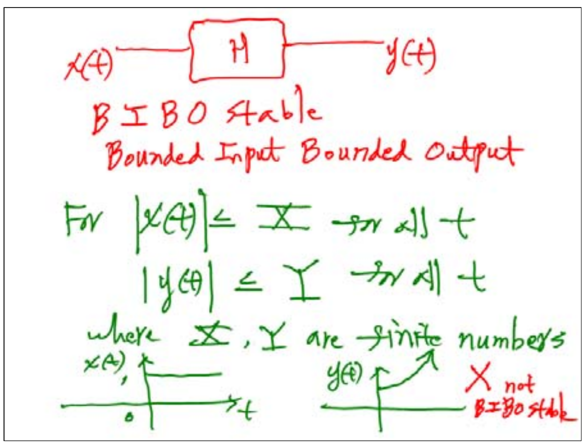

x(t) → H or T → y(t)
x₁(t) → H → y₁(t)
x₂(t) → H → y₂(t)
x(t) = a x₁(t) + b x₂(t)
→ H → a y₁(t) + b y₂(t)

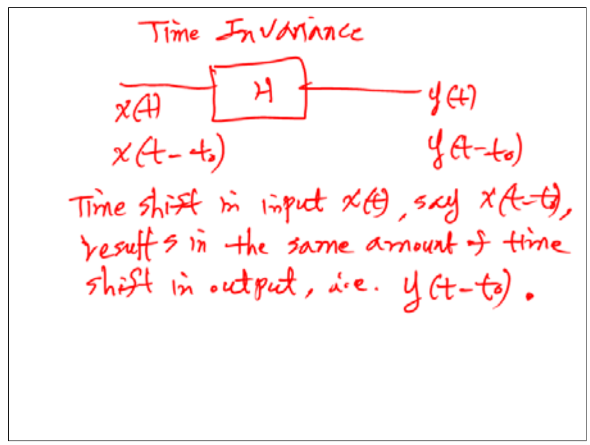

x(t) → H → y(t)
x(t − t₀) → H → y(t − t₀)
x₁(t) = u(t)
y₁(t) =
e^-t
x₂(t) = u(t − 2)
y₂(t) =
u(t−2) e^-(t−2)

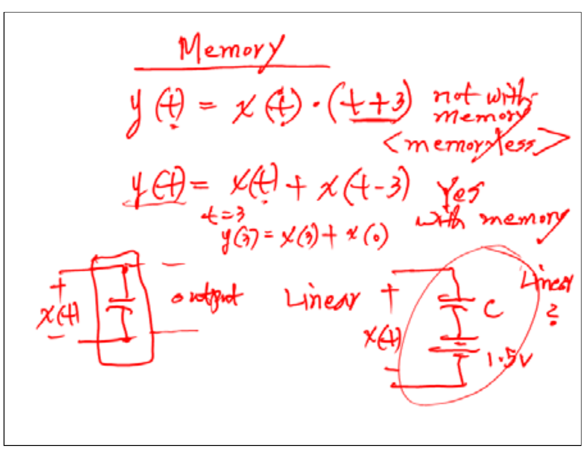

x₃(t) = u(t) − u(t − 2)
y₃(t) = ?
y₁(t) = u(t) e^-t
y₂(t) = u(t−2) e^-(t−2)
− u(t−2) e^-(t−2)
y₃ = y₁ − y₂
e^-2
−1 + e^-2

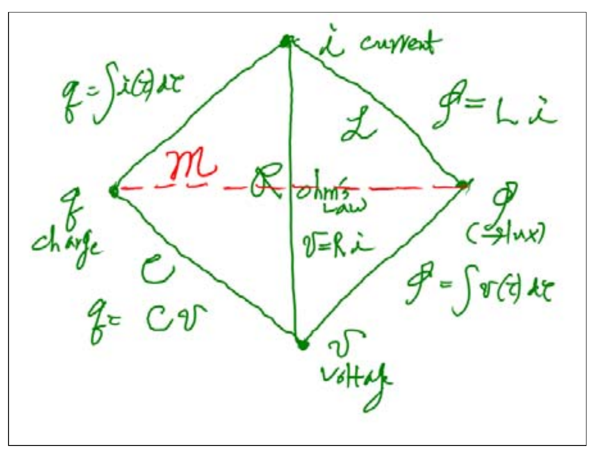

x1 → H → y1
x2 y2
x1 − x2 → y1 − y2
a x1
b x2
a
b
c
x1(t)
x2(t)
$v(t) = \frac{1}{c}\int_{-\infty}^{t} [a x_1(\tau) + b x_2(\tau)]\, d\tau$
Linear $= a\left(\frac{1}{c}\int_{-\infty}^{t} x_1(\tau)\, d\tau\right) + b\left(\frac{1}{c}\int_{-\infty}^{t} x_2(\tau)\, d\tau\right)$


x(t)
x(t) = t
1
0
t
sgn(t)
+1
−1
|x(t)|
x(t) sgn(t)


x(t)
H
y(t)
BIBO stable
Bounded Input Bounded Output
For |x(t)| ≤ X for all t
|y(t)| ≤ Y for all t
where X, Y are finite numbers
not BIBO stable


Time Invariance
x(t)
H
y(t)
x(t − t0)
y(t − t0)
Time shift in input x(t), say x(t−t0), results in the same amount of time shift in output, i.e. y(t−t0).


Memory
y(t) = x(t)·(t+3) not with memory
<memoryless>
y(t) = x(t) + x(t−3) Yes with memory
t=3
y(3) = x(3) + x(0)
x(t)
output
Linear
C
Linear ?
1.5V


i current
q = ∫ i(τ) dτ
φ = L i
L
M
R
ohm's Law
v = R i
q charge
φ (flux)
C
q = C v
φ = ∫ v(τ) dτ
v voltage

$$\varphi \quad ? \quad q$$

$$\varphi = f(q)$$

$$\frac{d}{dt}\varphi = v = \frac{d}{dt} f(q)$$

$$= \left[\frac{d f(q)}{dq}\right] \frac{dq}{dt} = i$$

$$v = \left[\frac{d f(q)}{dq}\right] i$$

memory resistor

$\boxed{\text{Memristor}}$