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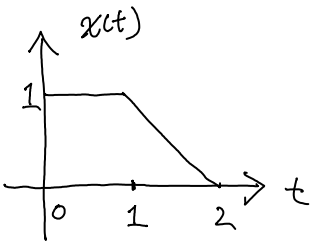
# Lecture 3

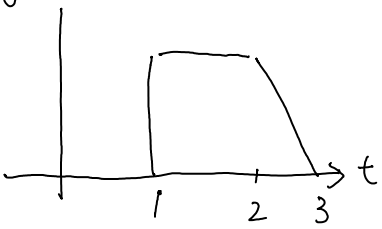
## ① Time shifting

$x(t) \longrightarrow x(t \pm k)$

ex/



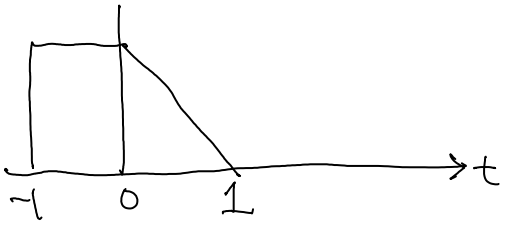

$y(t) = x(t-1) = ?$




| $x(t)$ | $y(t) = x(t-1)$ | $t$ | $y(t)$ |
|---|---|---|---|
| $0 = x(-2)$ | $x(-3) = 0$ | $-2$ | $x(-3) = 0$ |
| $0 = x(-1)$ | $x(-2) = 0$ | $-1$ | $x(-2) = 0$ |
| $1 = x(0)$ | $x(-1) = 0$ | $0$ | $x(-1) = 0$ |
| $1 = x(1)$ | $x(0) = 1$ | $1$ | $1$ |
| $0 = x(2)$ | $x(1) = 1$ | $2$ | $1$ |
| $0 = x(3)$ | $x(2) = 0$ | $3$ | $0$ |

Delay, implementable

ex $x(t+1)$




Psychic, non-implementable.

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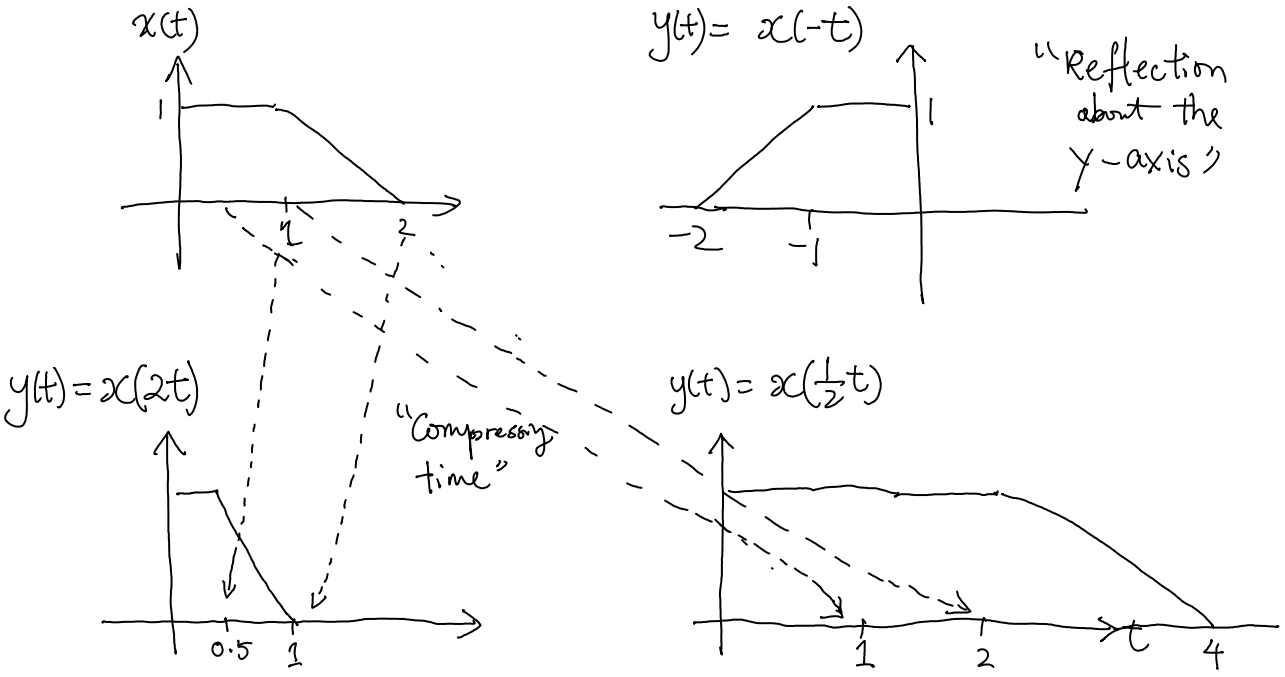
## ② Time ~~set~~ scaling




$$y(t) = x(at)$$

$a < 0 \Rightarrow$ flipping

$|a| > 1 \Rightarrow$ compressing

$|a| < 1 \Rightarrow$ dilating or stretching

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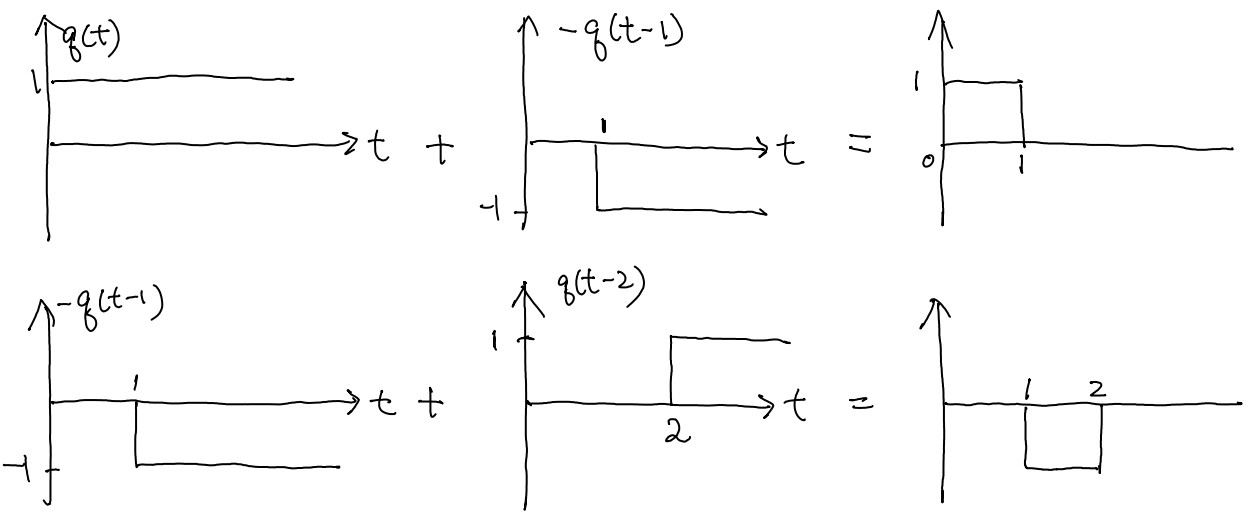
## ③ Adding two signals (or subtracting)

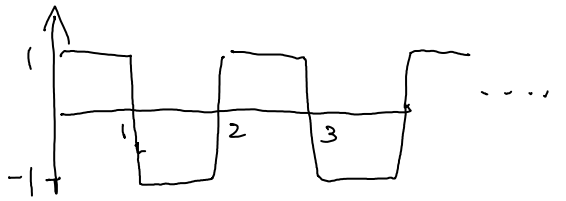
$$y(t) = x_1(t) + x_2(t)$$







Ex/




$$= q(t) - 2q(t-1) + 2q(t-2) - 2q(t-3) + 2q(t-4) - \cdots$$

Verify !!

④ Multiplication (division) of two signals

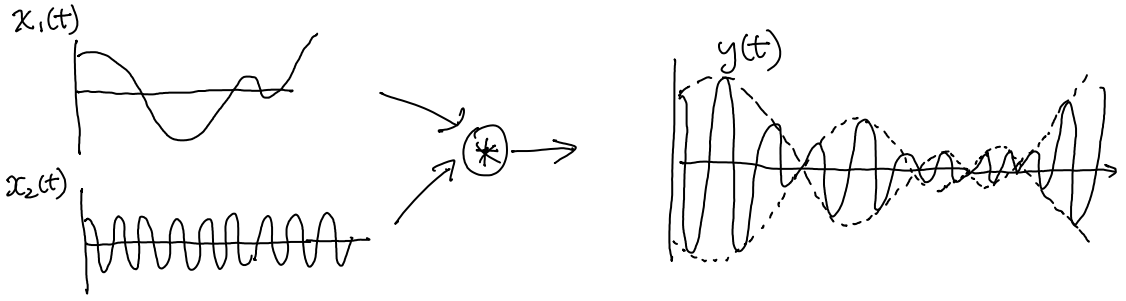
$$y(t) = x_1(t) \cdot x_2(t)$$

modulation (amplitude modulation AM)

$x_1(t)$ = message signal of low frequency
- audio signal (voltage)
- low freq. (10 Hz – 10 kHz)

$x_2(t)$ = carrier signal
- sinusoid ($A\cos(\omega_c t)$)
- $\omega_c$ = carrier frequency
  In US, $520\text{kHz} < \omega_c < 1610\text{ kHz}$

$y(t)$ = modulating signal
$= x_1(t) \cdot A\cos(\omega_c t)$




* Multiple access —— different signals can be transmitted through different $\omega_c$ sharing the same medium (air)
  ↖ carrier frequency

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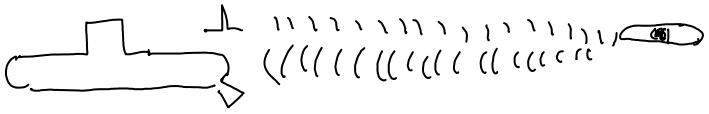
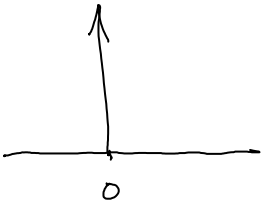
# Impulse $\delta(t)$


Distance = velocity · Time

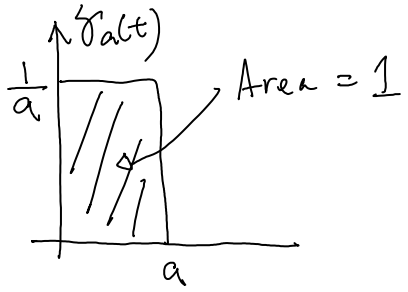


Ideal pulse — finite energy
— very-very short duration ($\Delta t = 0$)
— Impulse $\delta(t)$

$$\delta(t) = \begin{cases} \infty & t = 0 \quad (!?) \\ 0 & \text{everywhere else} \end{cases}$$




$$\int_{-\infty}^{\infty} \delta(t)\, dt = 1 \qquad \text{"Finite Energy"}$$




$$\delta(t) \triangleq \lim_{a \to 0} \delta_a(t)$$