CSE 311:
Data Communication

Instructor:

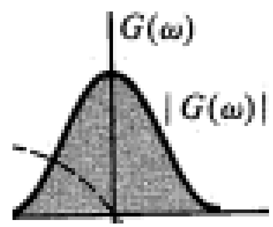
Dr. Md. Monirul Islam

Channel & signal Characteristics: *modulation*

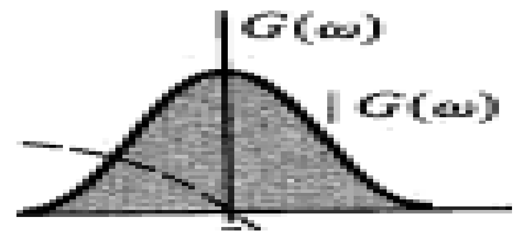
Review

- Use carrier signal to shift these 2 signals in different frequency positions

also called
Frequency division multiplexing (FDM)

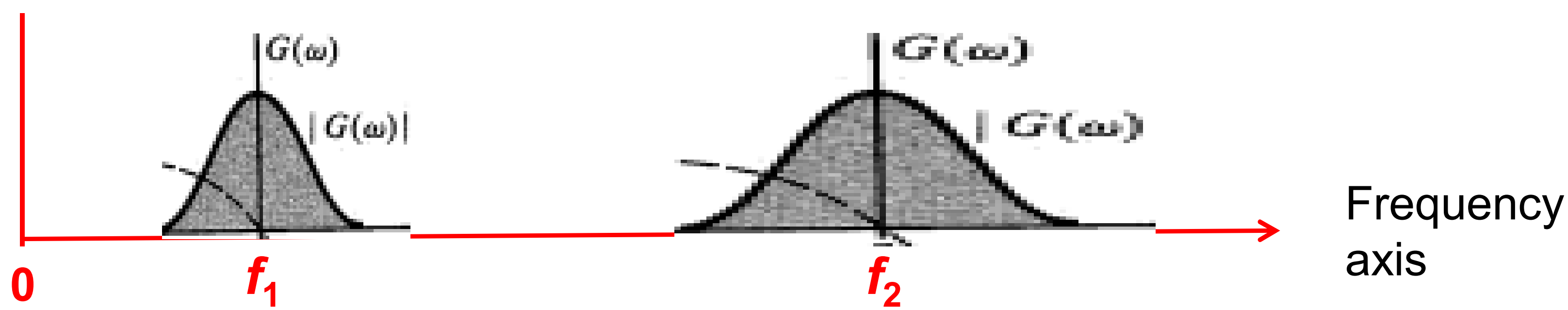


Baseband signal 1



Baseband signal 2

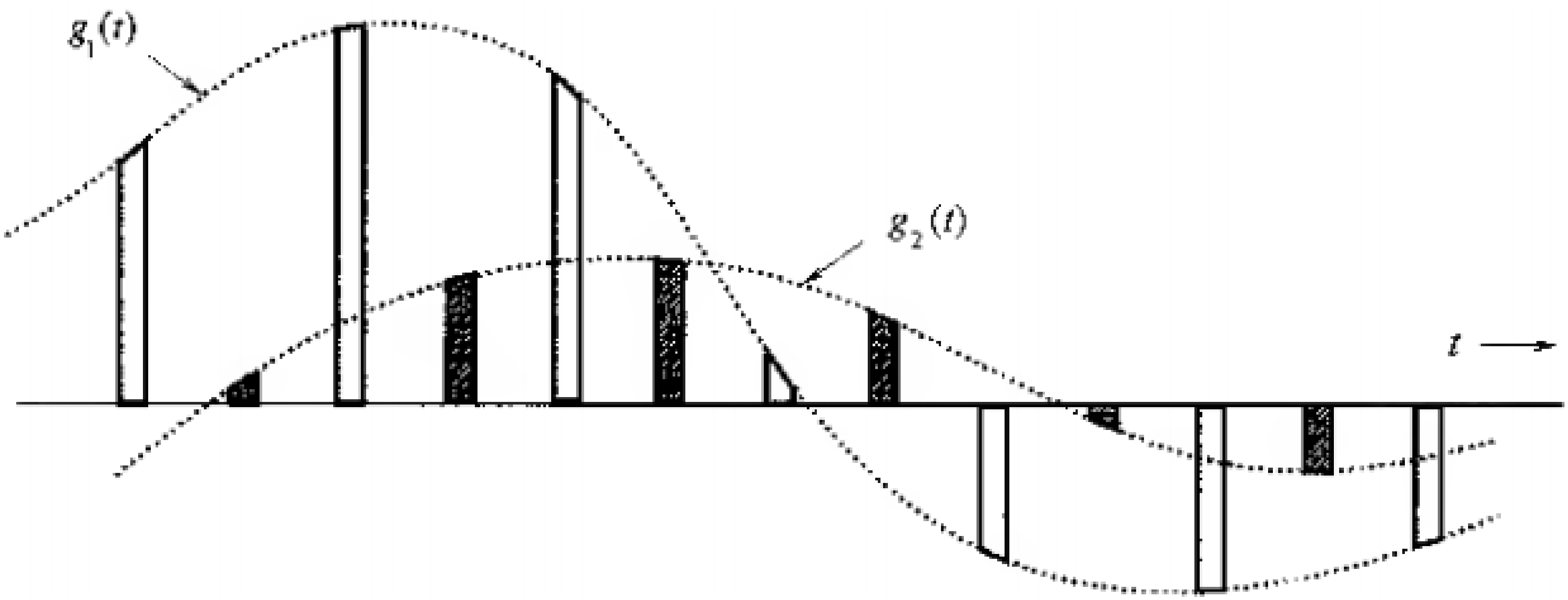
After modulation:



Channel & signal Characteristics: *modulation*

Review

- Time division multiplexing (TDM)
  - Interleave pulses from different signals in time domain signal



Channel & signal Characteristics: *DeModulation*

Review

- Done at the receiving end
  - Bandpass filter separates appropriate signal
  - Makes necessary corrections for amplitude, frequency and phase changes

Signal Characteristics: *digital source coding and error correction coding*

- 2 opposite procedures

- Digital source coding
  - An aggressive measure to reduce redundancy

- Error correction coding
  - A systematic addition of redundancy to detect/correct errors

Digital source Coding

- Removes redundancy
- Uses bandwidth as little as possible
- Related to randomness/predictibility in data

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Less randomness → More predictibility → Higher redundancy → Shorter codeword

Digital source Coding

- Removes redundancy
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- Related to randomness/predictibility in data

Less randomness → More predictibility → Higher redundancy → Shorter codeword

Higher randomness → Less predictibility → Lower redundancy → Longer codeword

Digital source Coding

- Example: Morse code
  - Frequently occurring letters e, t, a: shorter codes
  - Less frequent letters: longer codes

Less randomness → More predictibility → Higher redundancy → Shorter codeword

Higher randomness → Less predictibility → Lower redundancy → Longer codeword

Digital source Coding

No randomness $\Rightarrow$ NO news at all $\Rightarrow$ Nothing to transmit

- A message with probability *p*,

  its *randomness or entropy* = log (*1/p*) = -log (*p*)

Digital source Coding

No randomness → NO news at all → Nothing to transmit

- A message with probability p,
  its *randomness or entropy* = $\log(1/p) = -\log(p)$

What happens when $p = 0$ and $p = 1$?

Error correction coding

- Add systemic redundancy
- 50% of English text is redundant
- Difficult to recover if error occurs in reduced text

Error correction coding

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- Error Detection: adding parity bit

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Assume to transmit **0001**

Error correction coding

- Add systemic redundancy
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- Difficult to recover if error occurs
- Error Detection: adding parity bit

00011

Add this bit to make
even no. of 1's

Error correction coding

- Add systemic redundancy
- 50% of English text is redundant
- Difficult to recover if error occurs
- Error Detection: adding parity bit

00011

Add this bit to make even no. of 1's

Detects single bit error; however cannot detect even no. of errors or cannot locate or correct single bit error

Signals and systems

Topics

- Definition, classification and properties of signals
- Examples of some useful signals
- Fourier Series of Periodic Signals

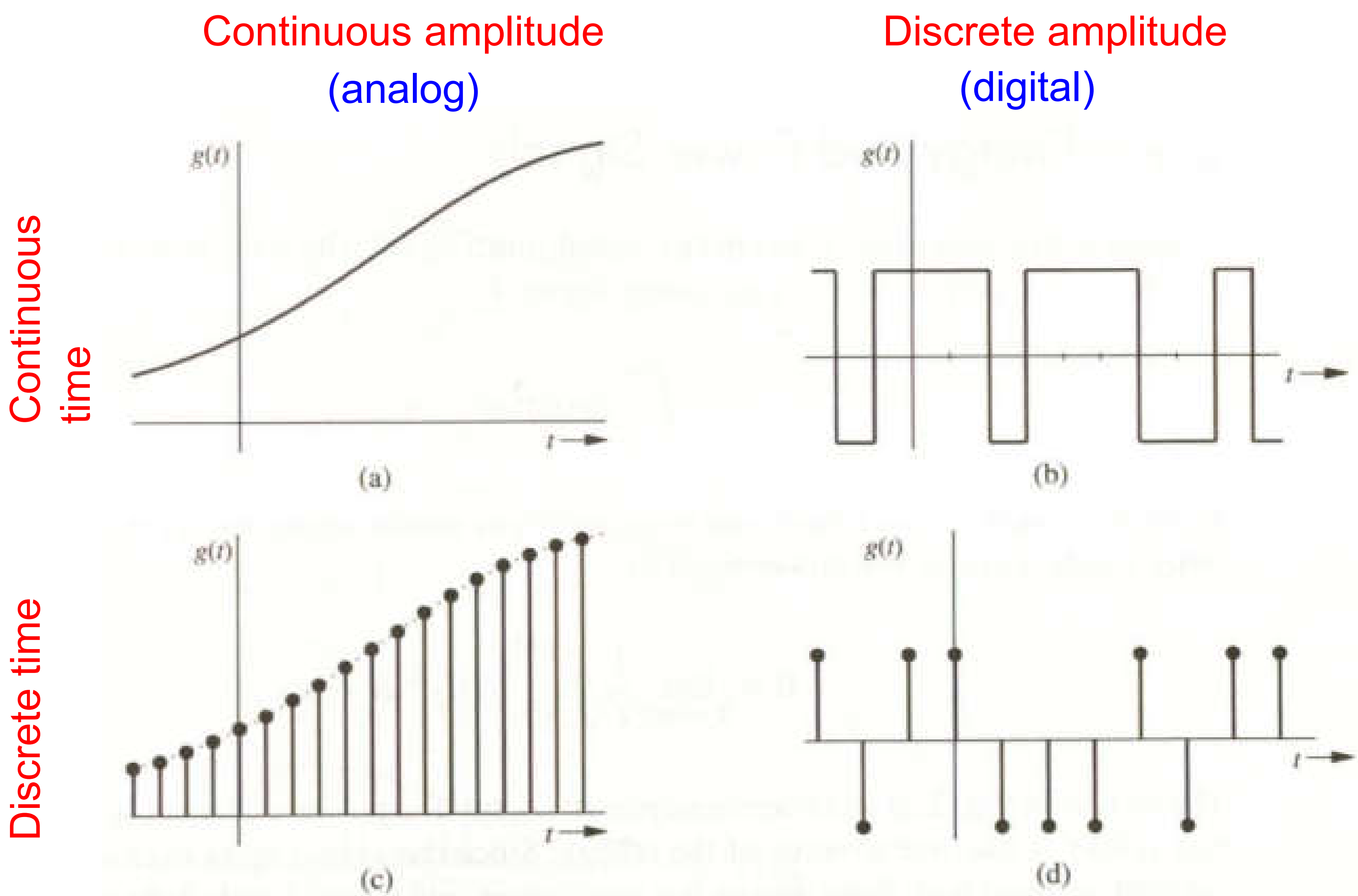
Classification of Signals

Review

- Based on continuity in time axis
  – Continuous time
  – Discrete time
- Based on continuity in amplitude axis
  – Continuous amplitude (analog)
  – Discrete amplitude (digital)

Classification of Signals

Review



Periodic and Aperiodic signal

- Signal $g(t)$ is periodic for a positive constant T_0 so that

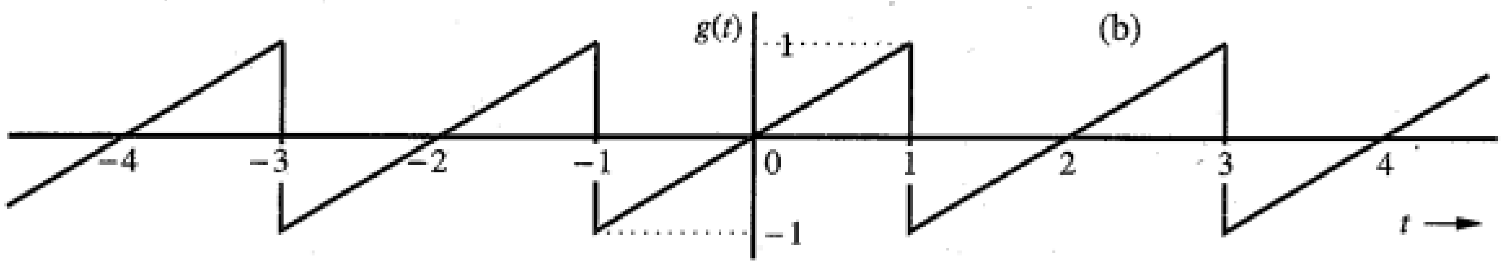
$$g(t) = g(t + T_0) \quad \text{for all } t$$

- Smallest T_0 is its period

- A signal is aperiodic if NOT periodic

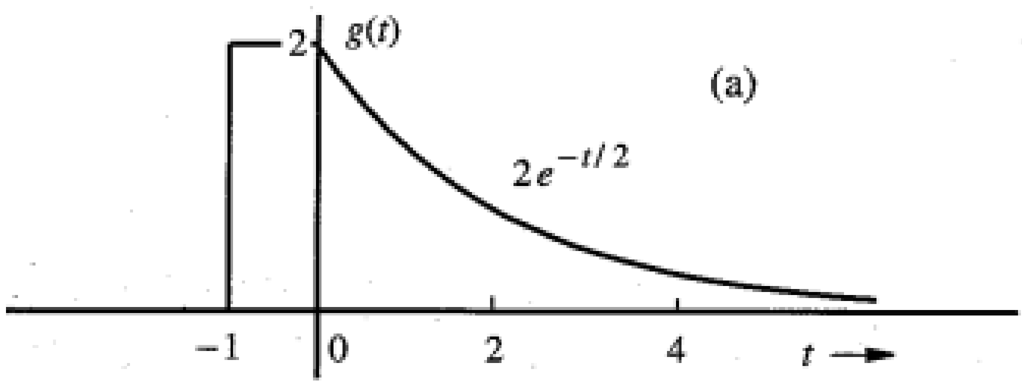
Periodic and Aperiodic signal

Periodic signal



Period, T_0 =2

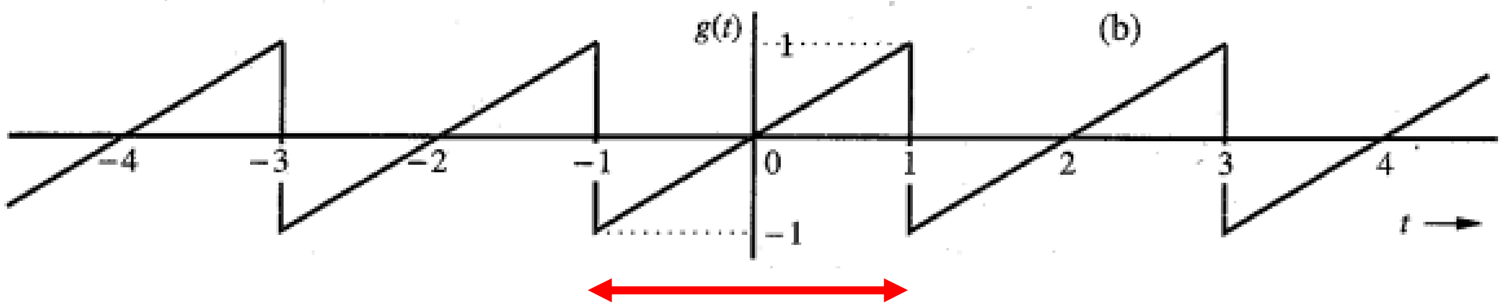
Aperiodic signal



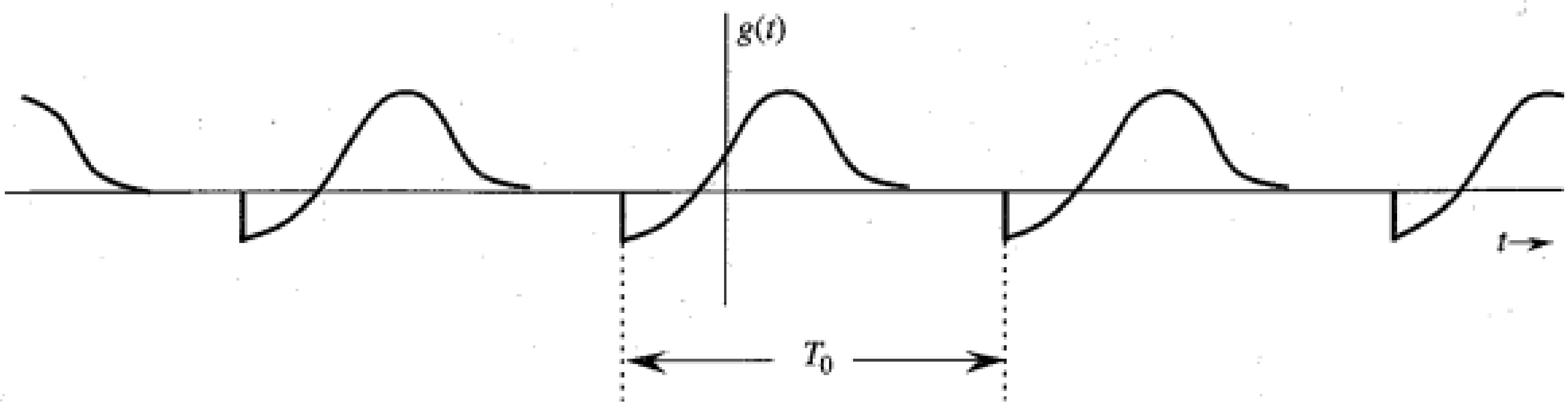
Periodic and Aperiodic signal

- Periodic signal starts at t = -α and continues forever

Periodic signal



Period, T_0 =2



Periodic and Aperiodic signal

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- cannot start at an finite time, say, $t = 0$, otherwise

  $g(t) = g(t + T_0)$ cannot be satisfied

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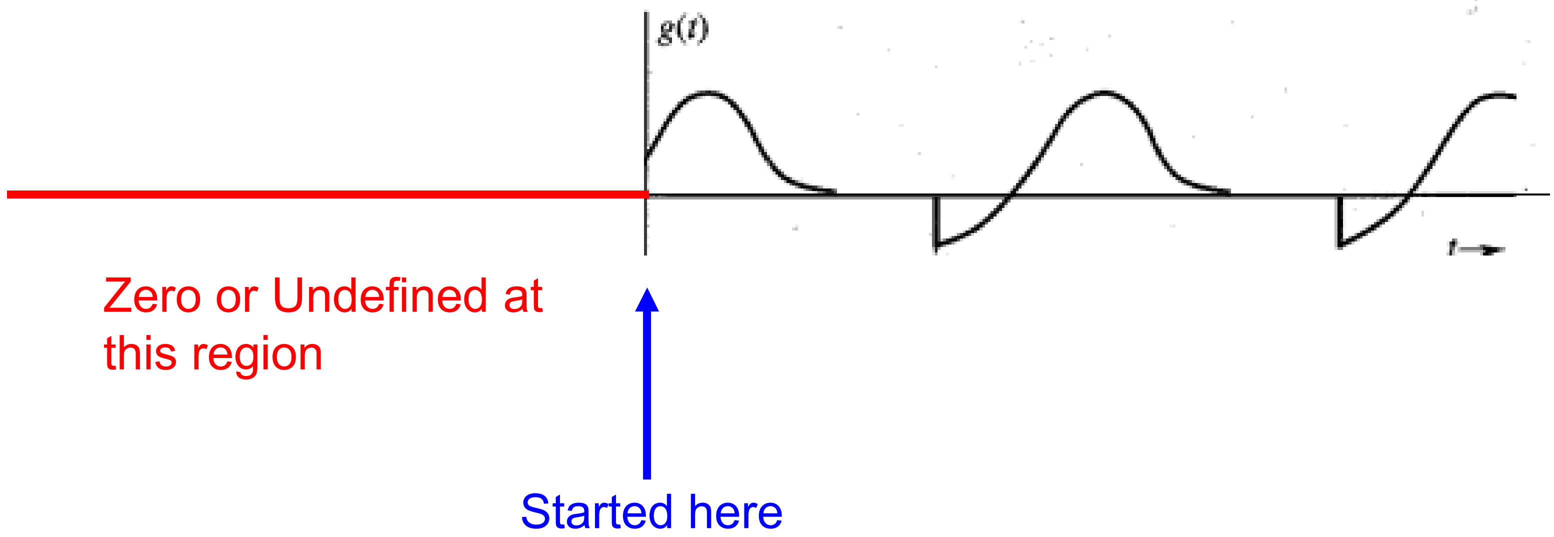

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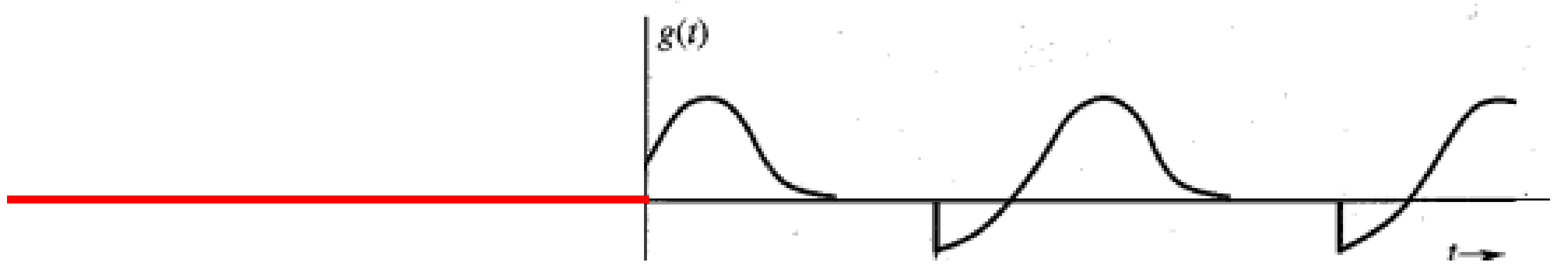


Zero or Undefined at
this region

At $t = -T_0$, $g(t) \neq g(t + T_0)$

Energy and Power signals

- Energy Signal: finite E_g

$$E_g = \int_{-\infty}^{\infty} g^2(t)\,dt < \infty$$

- Power signal: finite P_g

$$0 < P_g = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} g^2(t)\,dt < \infty$$

Energy and Power signals

$$E_g = \int_{-\infty}^{\infty} g^2(t)dt < \infty$$

$$0 < P_g = \lim_{T \to \infty} \frac{1}{T} \int_{-T/2}^{T/2} g^2(t)dt < \infty$$

- Finite E_g signal has zero P_g
- Finite P_g Signal has infinite E_g
- A signal CANNOT be both energy and power signal
- Real life signals are energy signals
- Power signals have infinite duration; impractical to generate
- Periodic signals are power signals

Deterministic and Random signals

- Deterministic
  - has complete physical description, mathematically or graphically
- Random
  - has only probabilistic description, e.g., mean value, rms, distribution
- All message signals are random

Signal Properties
Time shifting property

- Whatever happens in $g(t)$ at t second also happens in $\phi(t)$ T seconds later at instant $t + T$

$$\phi(t + T) = g(t)$$

Or,

$$\phi(t) = g(t - T)$$

Signal Properties

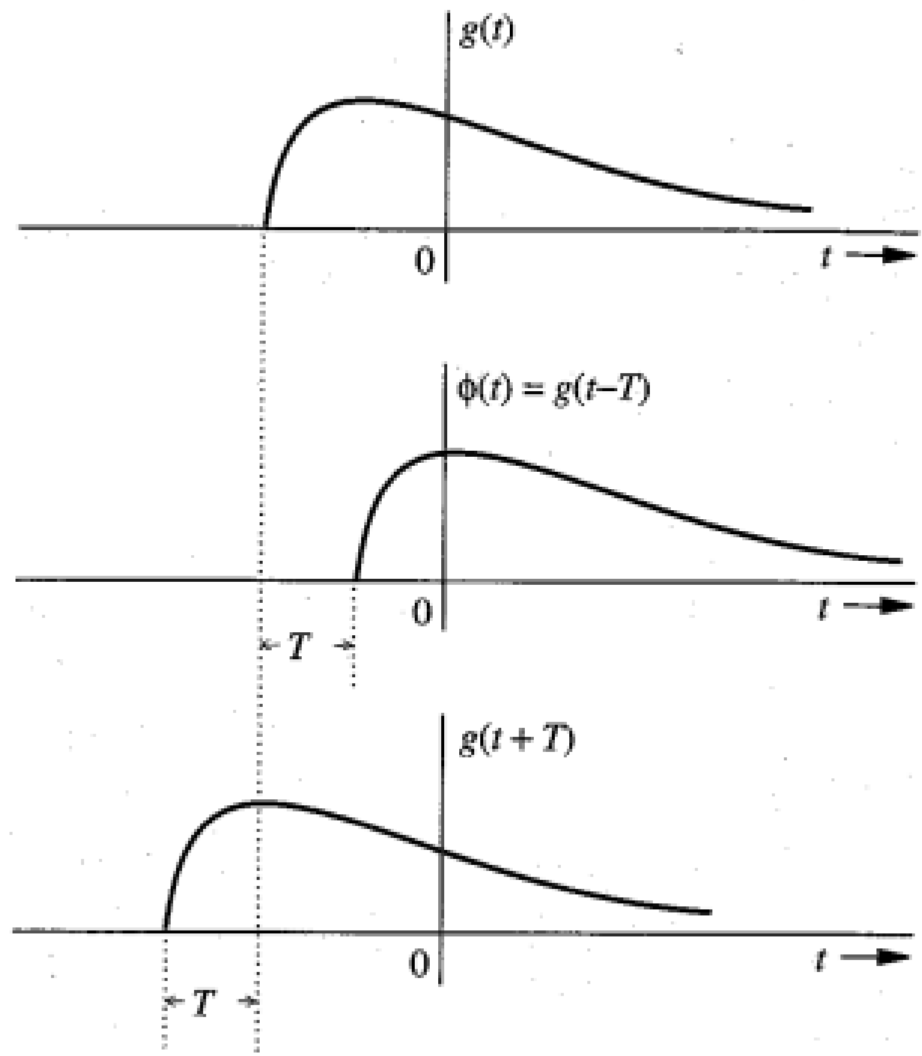
Time shifting property

$$\phi(t+T) = g(t)$$

$$\phi(t) = g(t-T)$$

Beginning T
seconds later

Beginning T
seconds earlier



Signal Properties
Time scaling property

- Compression or expansion
- Compression:
  - Whatever happens in $g(t)$ at t second also happens in $\phi(t)$ at t/a

$$\phi(t) = g(at),\ a > 1$$

Signal Properties
Time scaling property

- Compression or expansion
- Compression:
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$$\phi(t) = g(at), a > 1$$

- Expansion:
  - Whatever happens in $g(t)$ at t second also happens in $\phi(t)$ at at

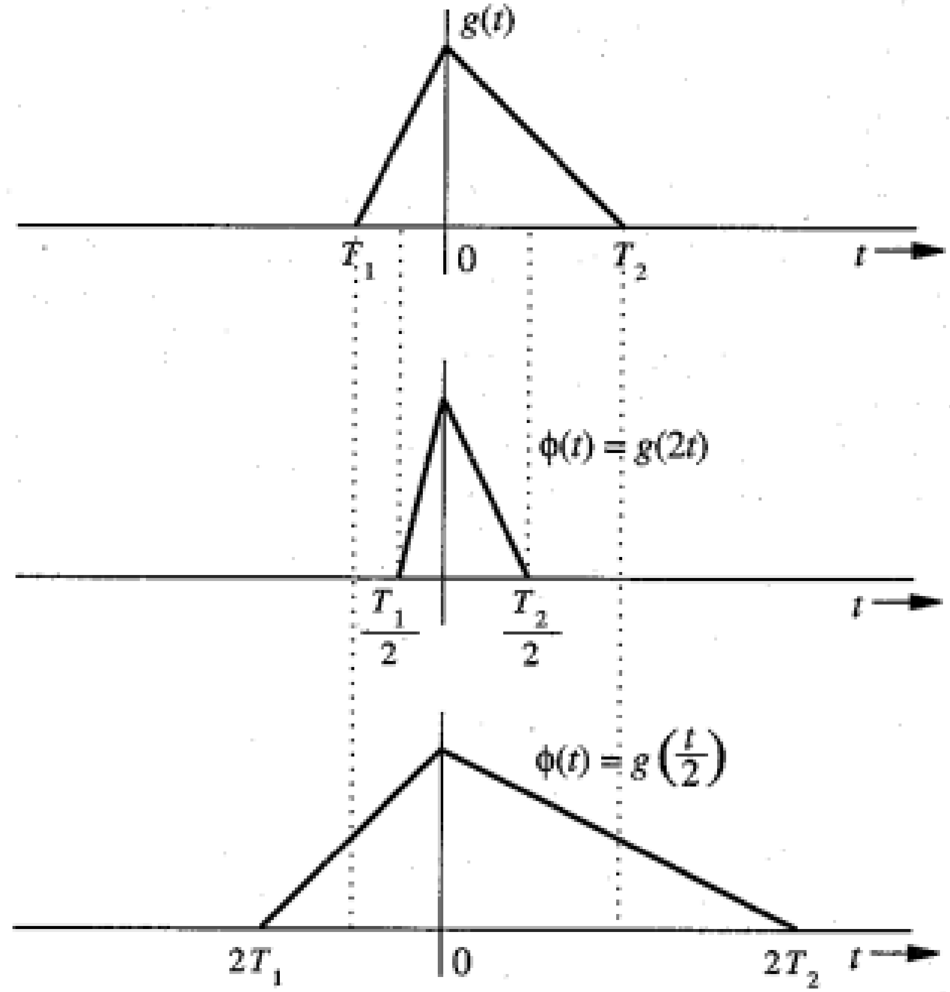
$$\phi(t) = g\left(\frac{t}{a}\right), a > 1$$

Signal Properties

Time scaling property

$$\phi(t) = g(at)$$

$$\phi(t) = g\left(\frac{t}{a}\right)$$



Compression

Expansion

Signal Properties
Time inversion property

- Mirroring about vertical axis
- Whatever happens in $g(t)$ at t second also happens in $\phi(t)$ at $-t$
- Similar to time scaling where a = -1

$$\phi(-t) = g(t)$$

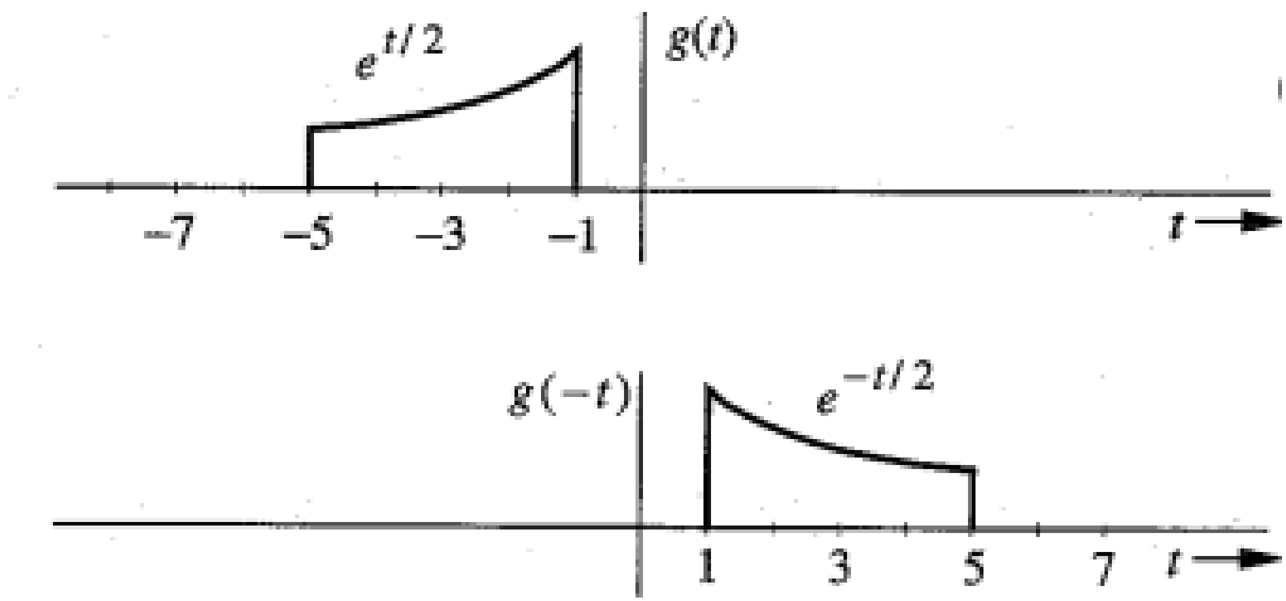
$$\phi(t) = g(-t)$$

Signal Properties

Example of Time inversion property

$$\phi(-t) = g(t)$$

$$\phi(t) = g(-t)$$



Unit Impulse Signal

- One of the most important signals, $\delta(t)$
- Also know as Dirac delta function

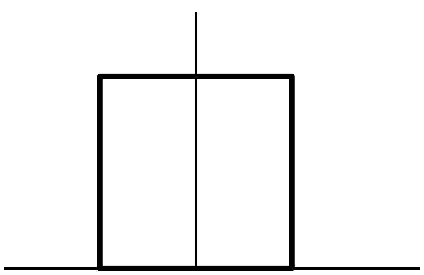
$$\delta(t) = \begin{cases} \infty & \text{if } \ t = 0 \\ 0 & \text{if } \ t \neq 0 \end{cases}$$

with the constraint,

$$\int_{-\infty}^{\infty} \delta(t)dt = 1$$

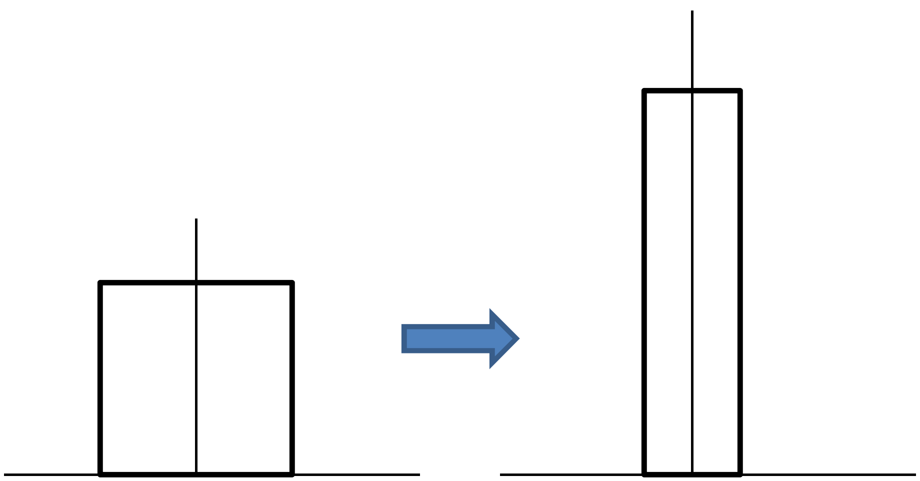
Unit Impulse Signal

A function with unit area under curve



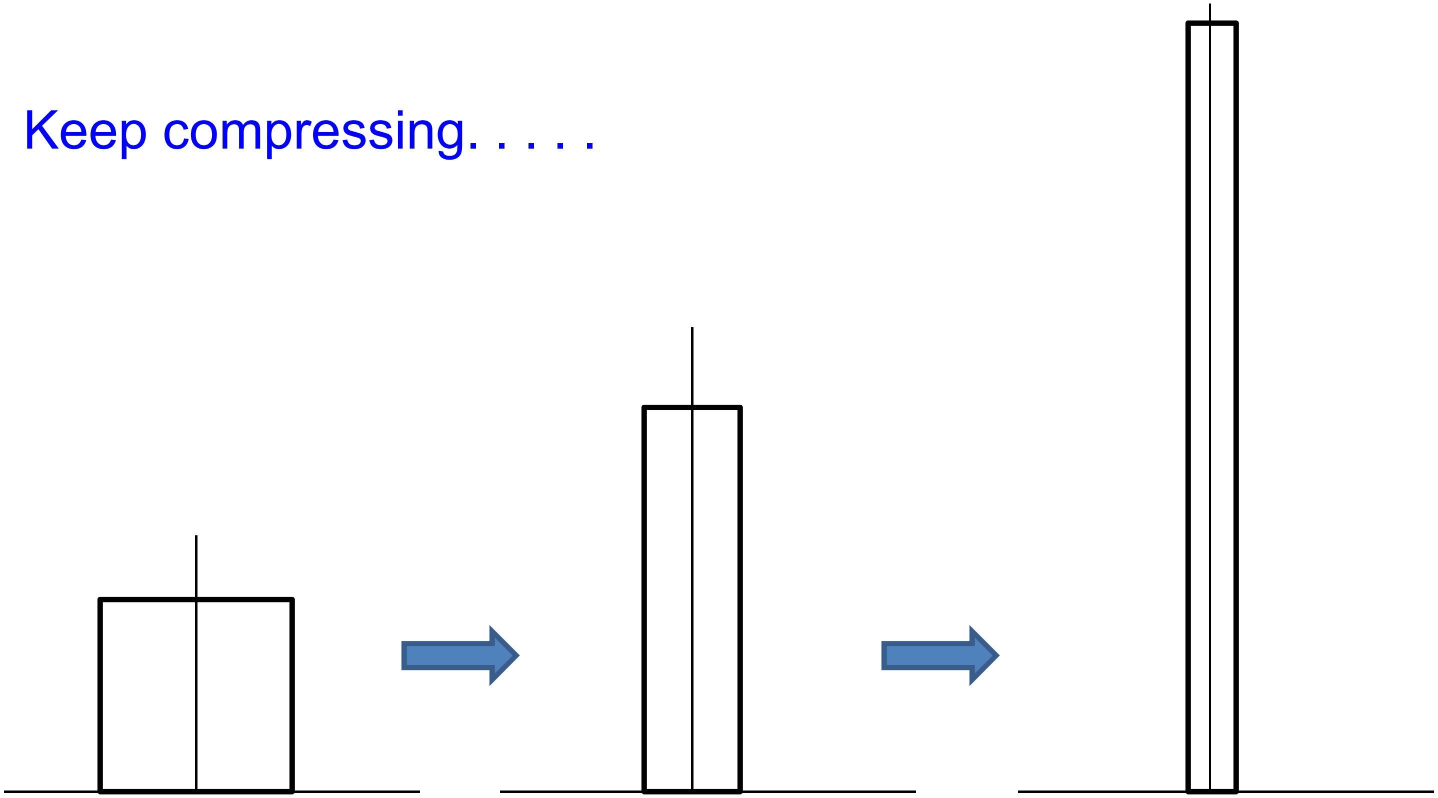
Unit Impulse Signal

Compress the function leaving
the area unchanged



Unit Impulse Signal

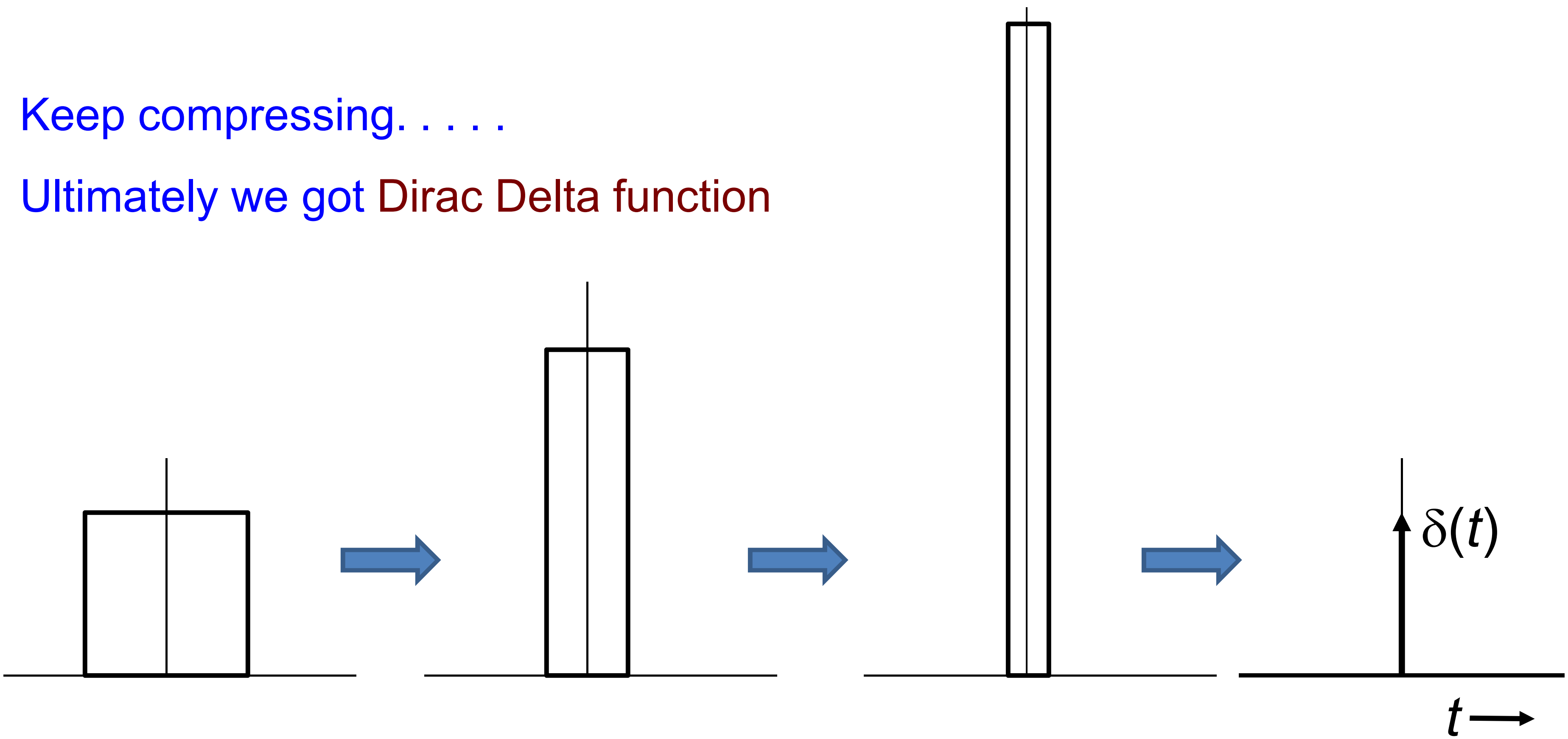
Keep compressing. . . . .



Unit Impulse Signal

Keep compressing. . . . .

Ultimately we got Dirac Delta function



Dirac Delta Function

Unit Impulse Signal

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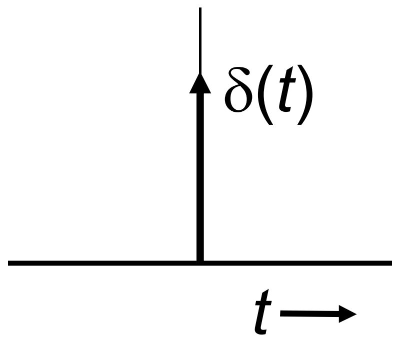
$$\int_{-\infty}^{\infty} \delta(t)\,dt = 1$$



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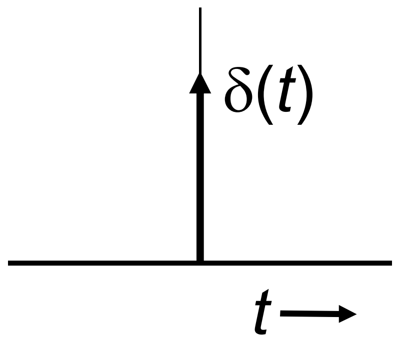
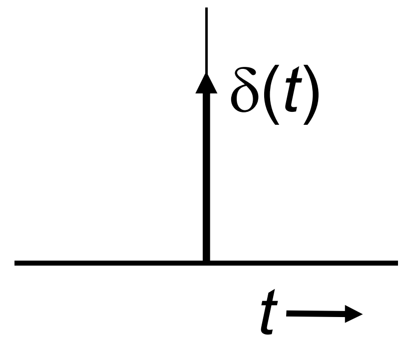
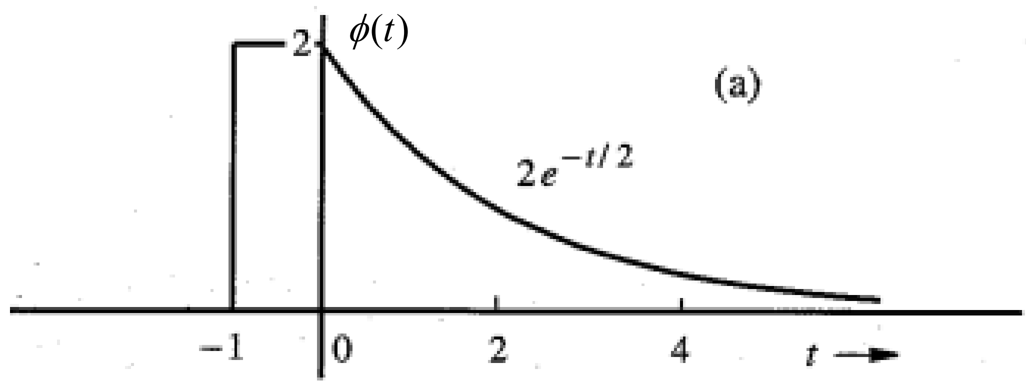


- Impulse location is at *t* =0

Multiplication of a Function by Impulse

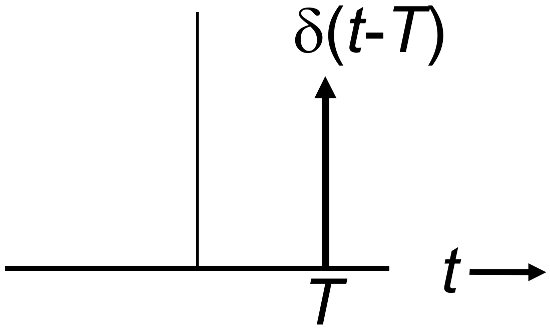
$$\phi(t)\delta(t) = \phi(0)\delta(t)$$

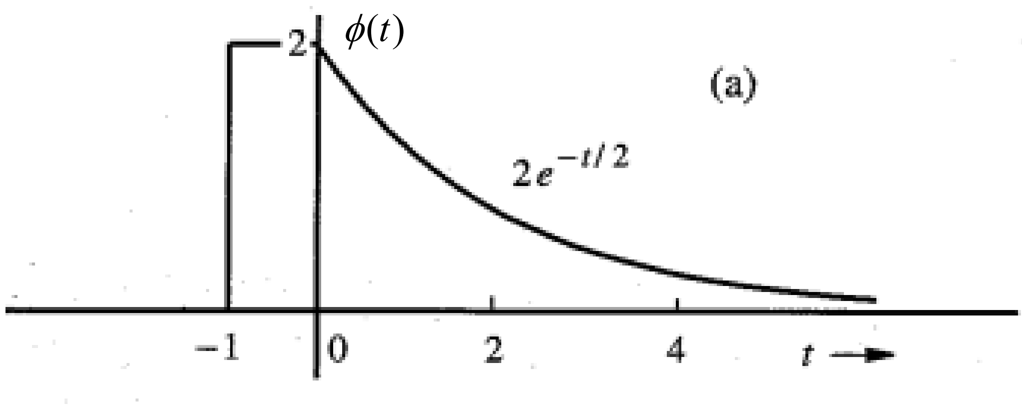




Multiplication of a Function by Impulse

$$\phi(t)\delta(t-T) = \phi(T)\delta(t-T)$$

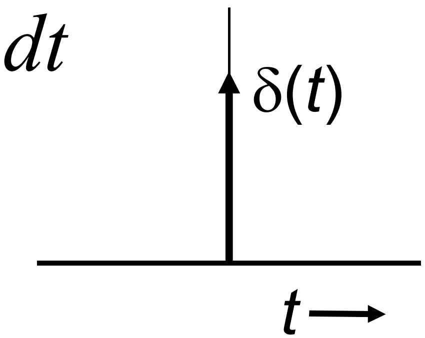


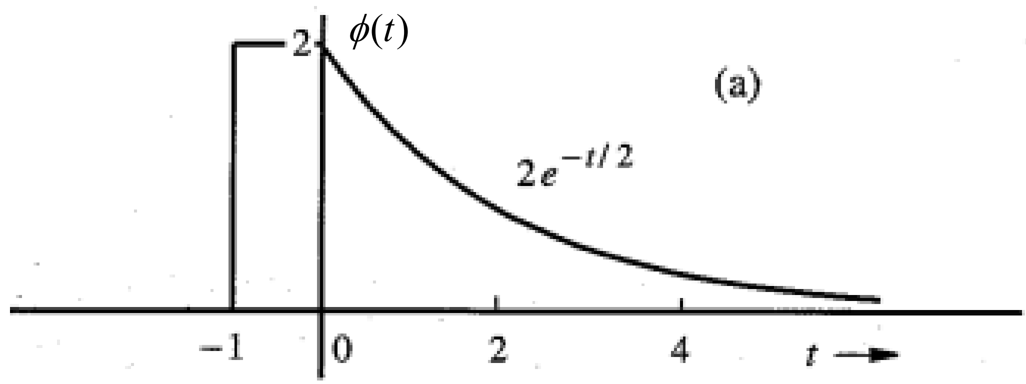


Sampling Property of the Unit Impulse Function

$$\int_{-\infty}^{\infty} \delta(t)\phi(t)dt = \phi(0)\int_{-\infty}^{\infty} \delta(t)dt$$

$$= \phi(0)$$





Sampling Property of the Unit Impulse Function

$$\int_{-\infty}^{\infty} \delta(t-T)\phi(t)dt$$

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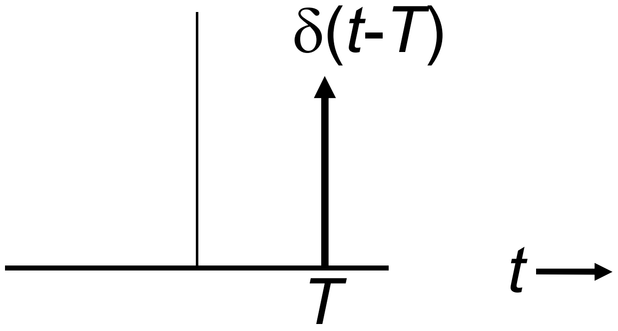
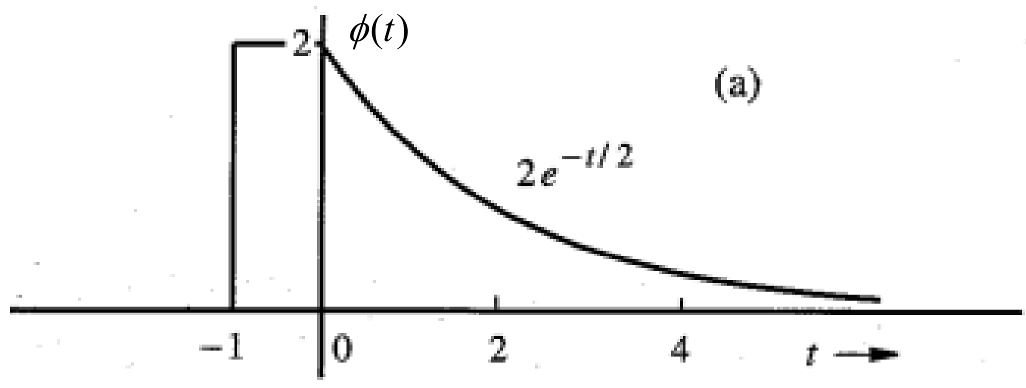
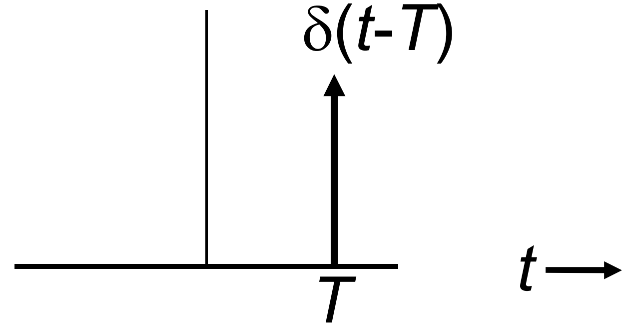


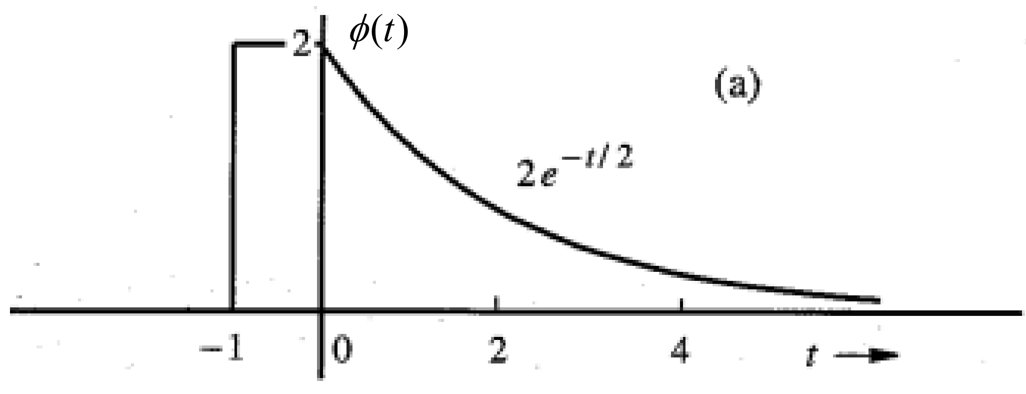


Sampling Property of the Unit Impulse Function

$$\int_a^b \delta(t-T)\phi(t)\,dt$$

$$= \phi(T)\int_a^b \delta(t-T)\,dt$$





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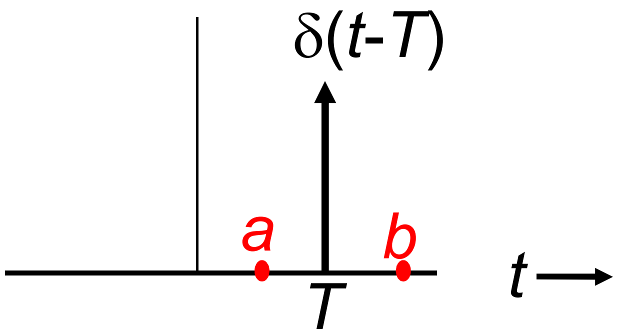

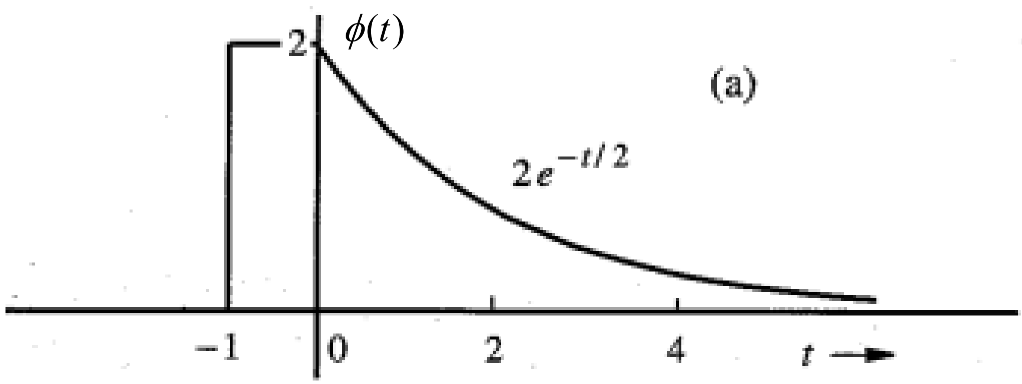

Sampling Property of the Unit Impulse Function

$$\int_a^b \delta(t-T)\phi(t)\,dt$$

$$= \phi(T)\int_a^b \delta(t-T)\,dt$$

$$= \begin{cases} \phi(T) & a \le T \le b \\ 0 & otherwise \end{cases}$$