Signals and Sampling

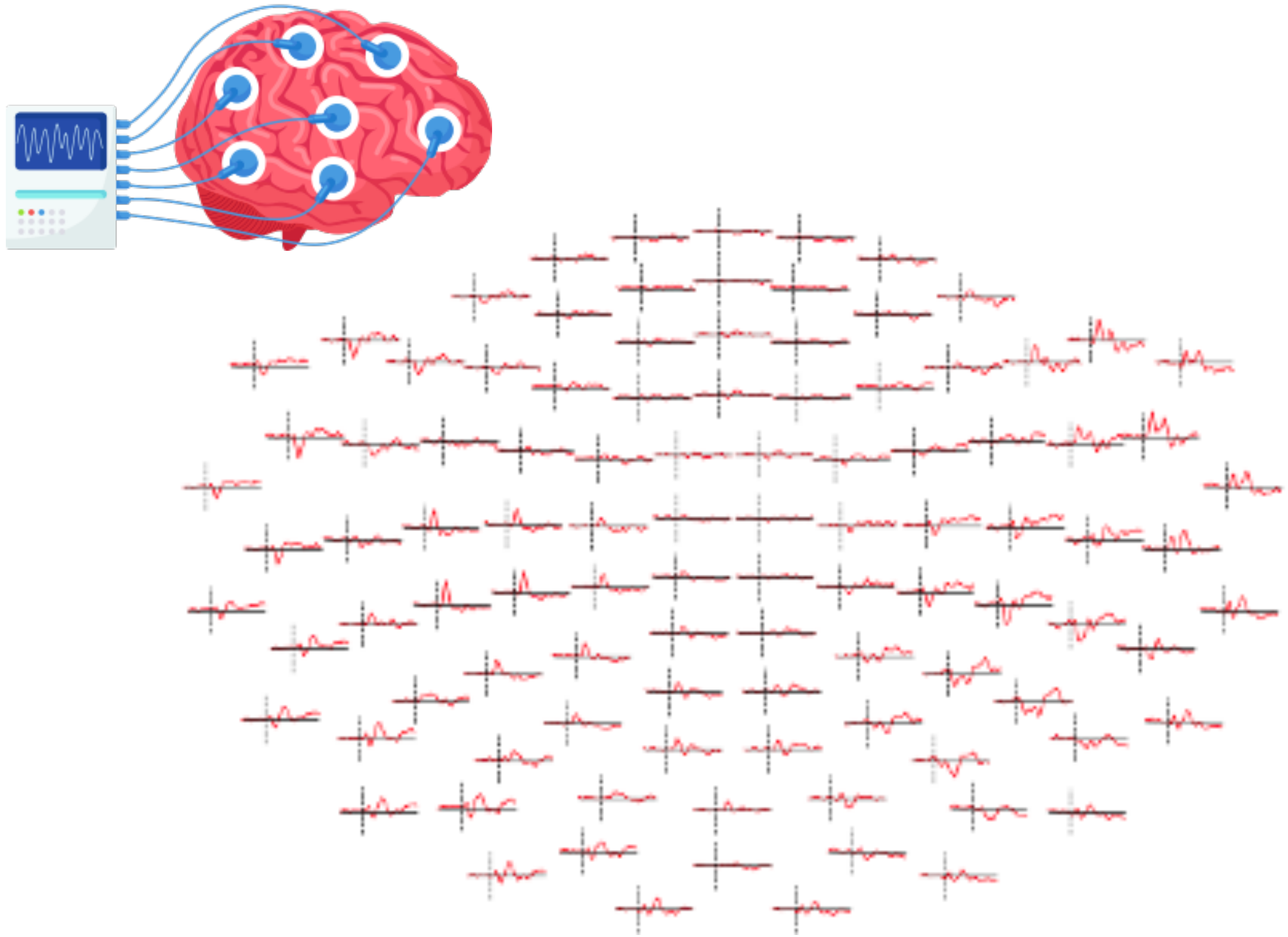
Itthi Chatnuntawech

Signals

Neural Spiking

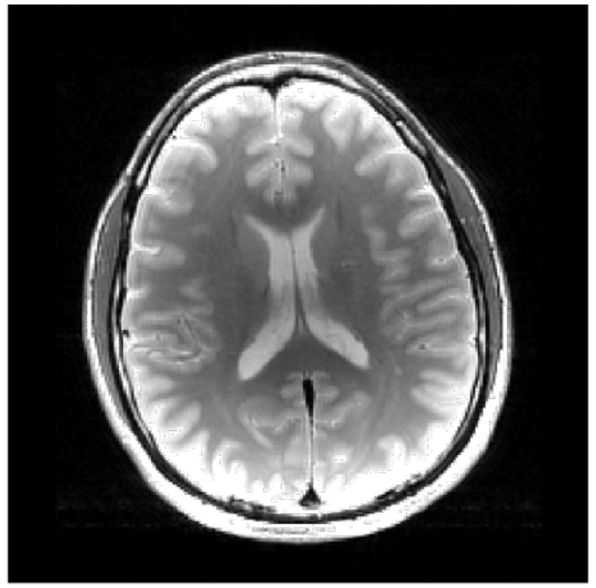
Dayan P and Abbott LF. MIT Press (2005)
Chestek CA et al. JNeurosci (2007)

EGG



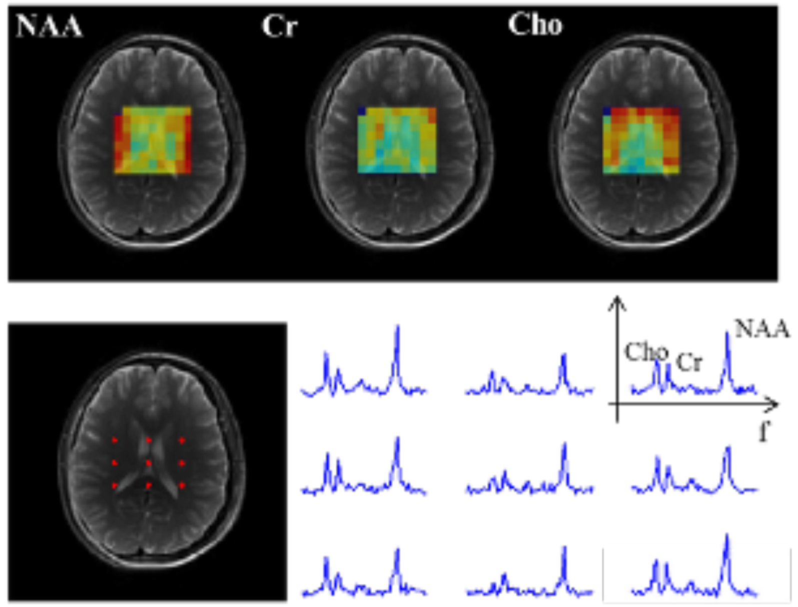
MNE's overview of MEG/EEG analysis with MNE-Python

MRI



Chatnuntawech et al. MRI (2016)

MRSI



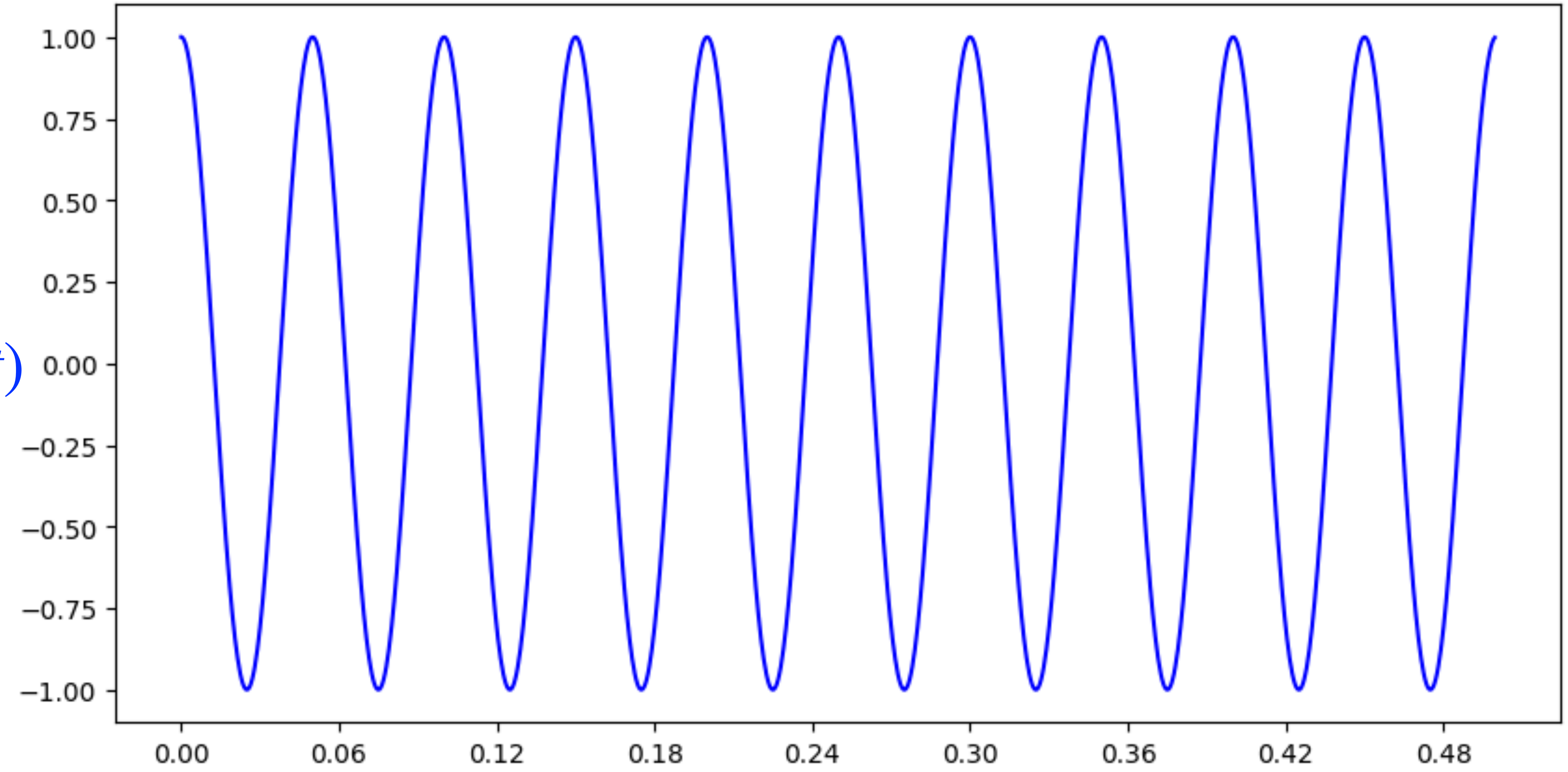
Chatnuntawech et al. MRM (2015)

Signals

Signal - A function of one or more independent variables

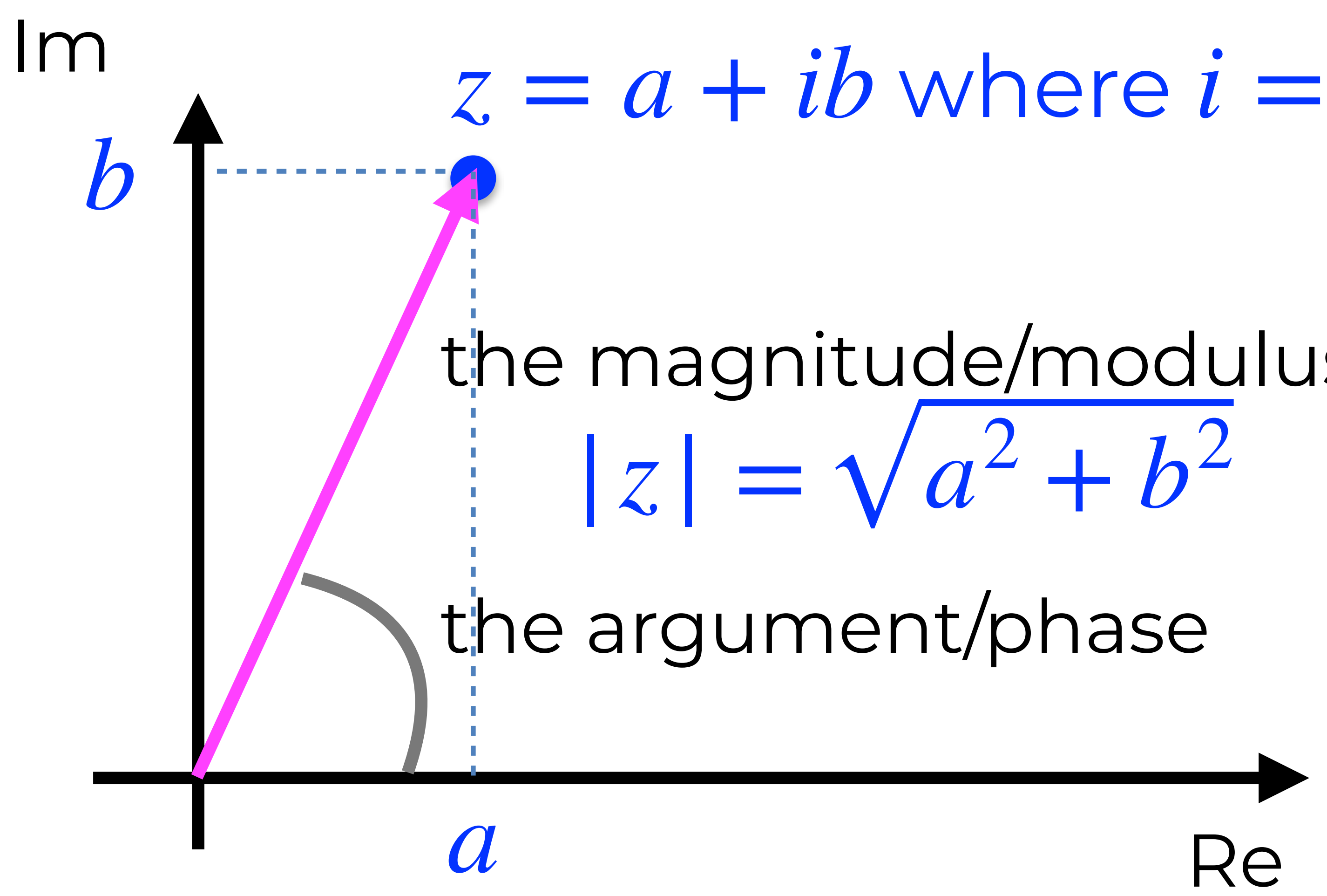
real-valued signal

$x(t) = \cos(2\pi \times 20t)$



Time (seconds), t

Complex-valued Signals



$z = a + ib$ where $i = \sqrt{-1}$

the magnitude/modulus

$$|z| = \sqrt{a^2 + b^2}$$

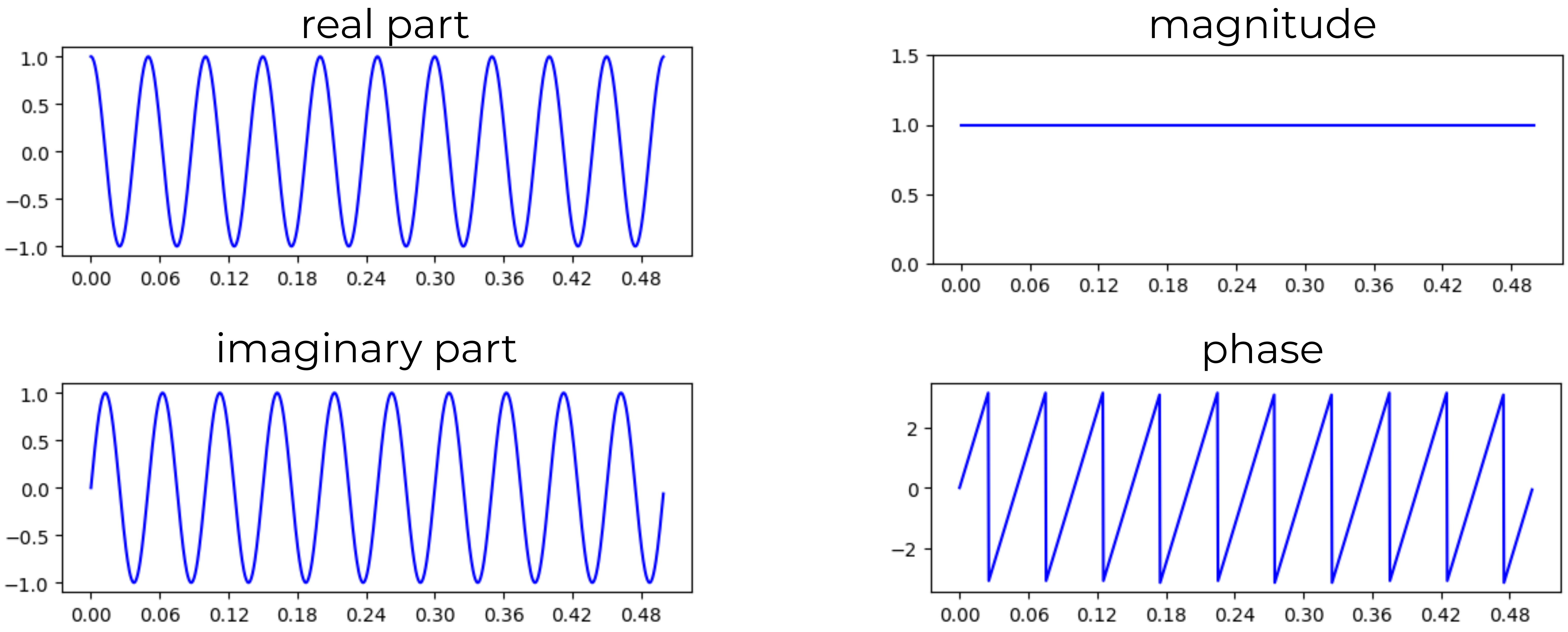
the argument/phase

$z = a + jb$ where $j = \sqrt{-1}$

Electrical and control system engineers use j instead of i

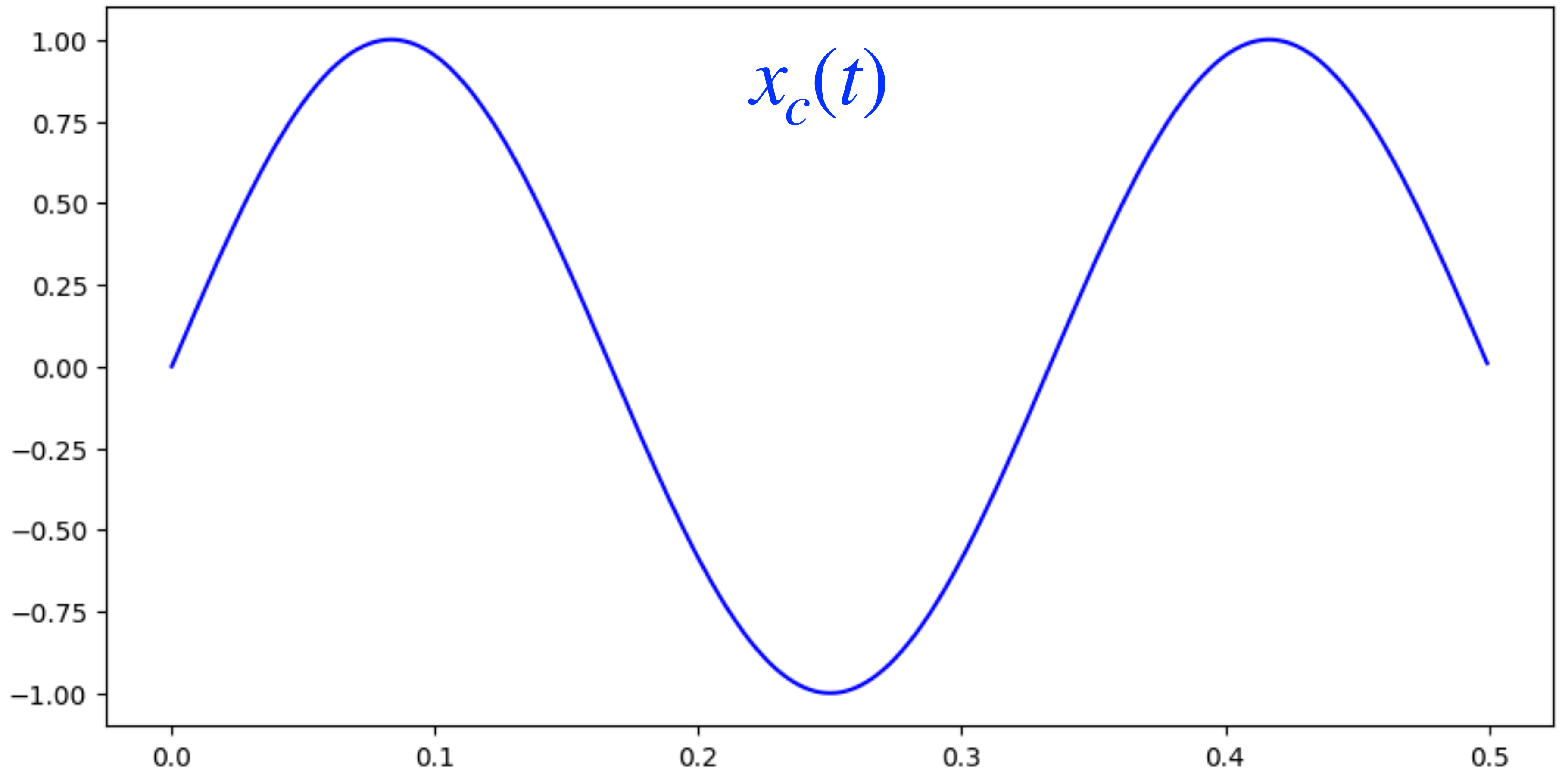
Complex-valued Signals

$$x(t) = e^{j2\pi\times 20t} = \cos(2\pi \times 20t) + j\sin(2\pi \times 20t)$$



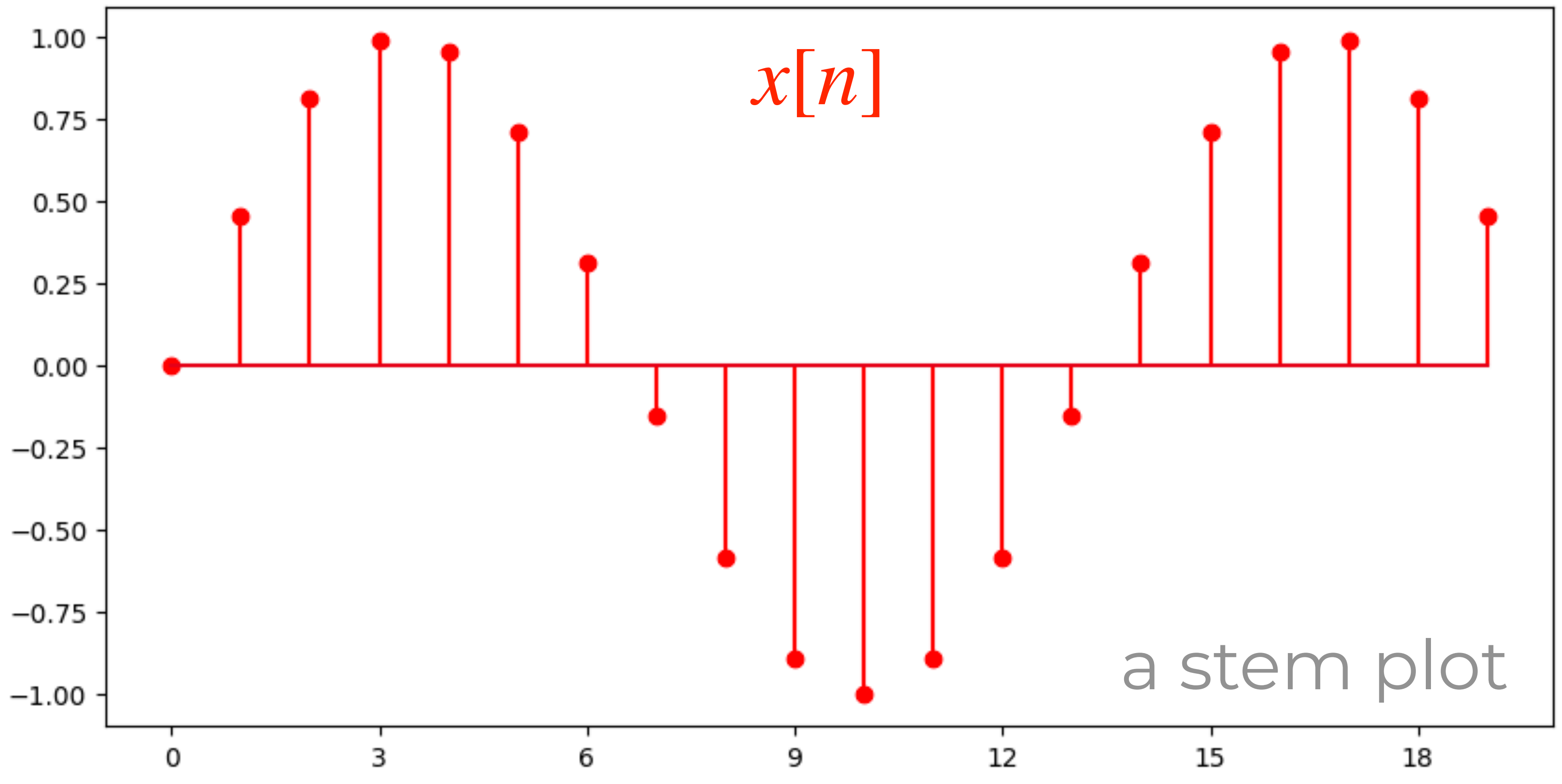
Continuous- and Discrete-Time Signals

continuous-time signal



continuous independent variable, t

discrete-time signal



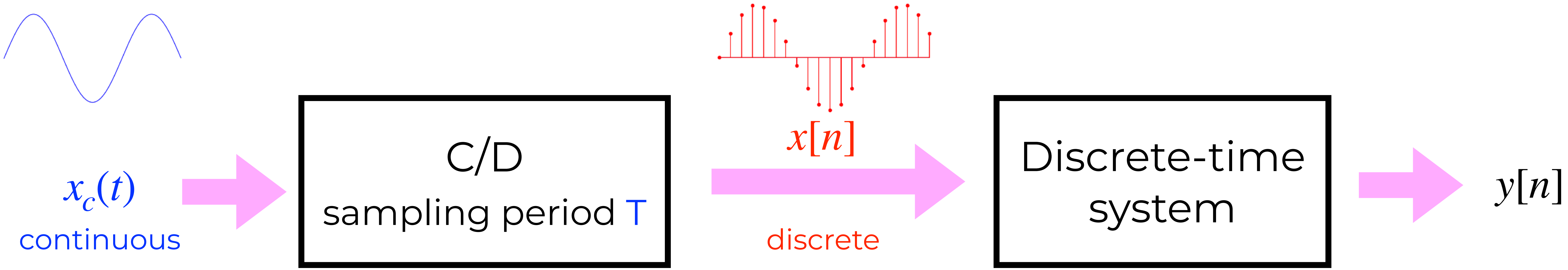
integer variable, n

$$[0,\ 0.4540,\ 0.8090,\ \ldots,\ 0.8090,\ 0.4540]$$

a sequence of 20 numbers in this case

Discrete-Time Signal Processing

Many applications make use of discrete-time technology to process signals that started out as continuous-time signals.



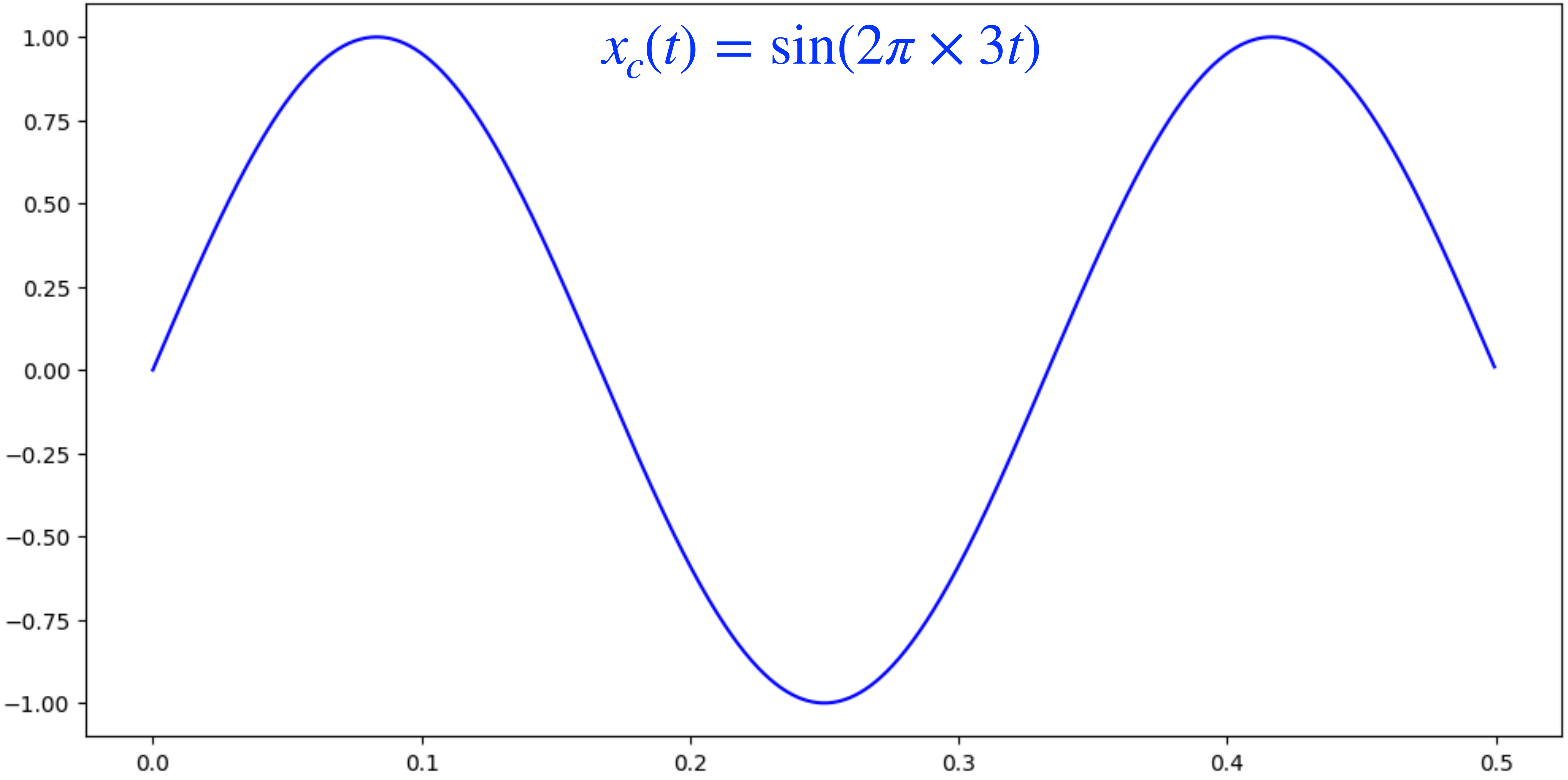
In many contexts, discrete-time signal processing is

- More flexible
- Less expensive
- Programmable
- Easily reproducible

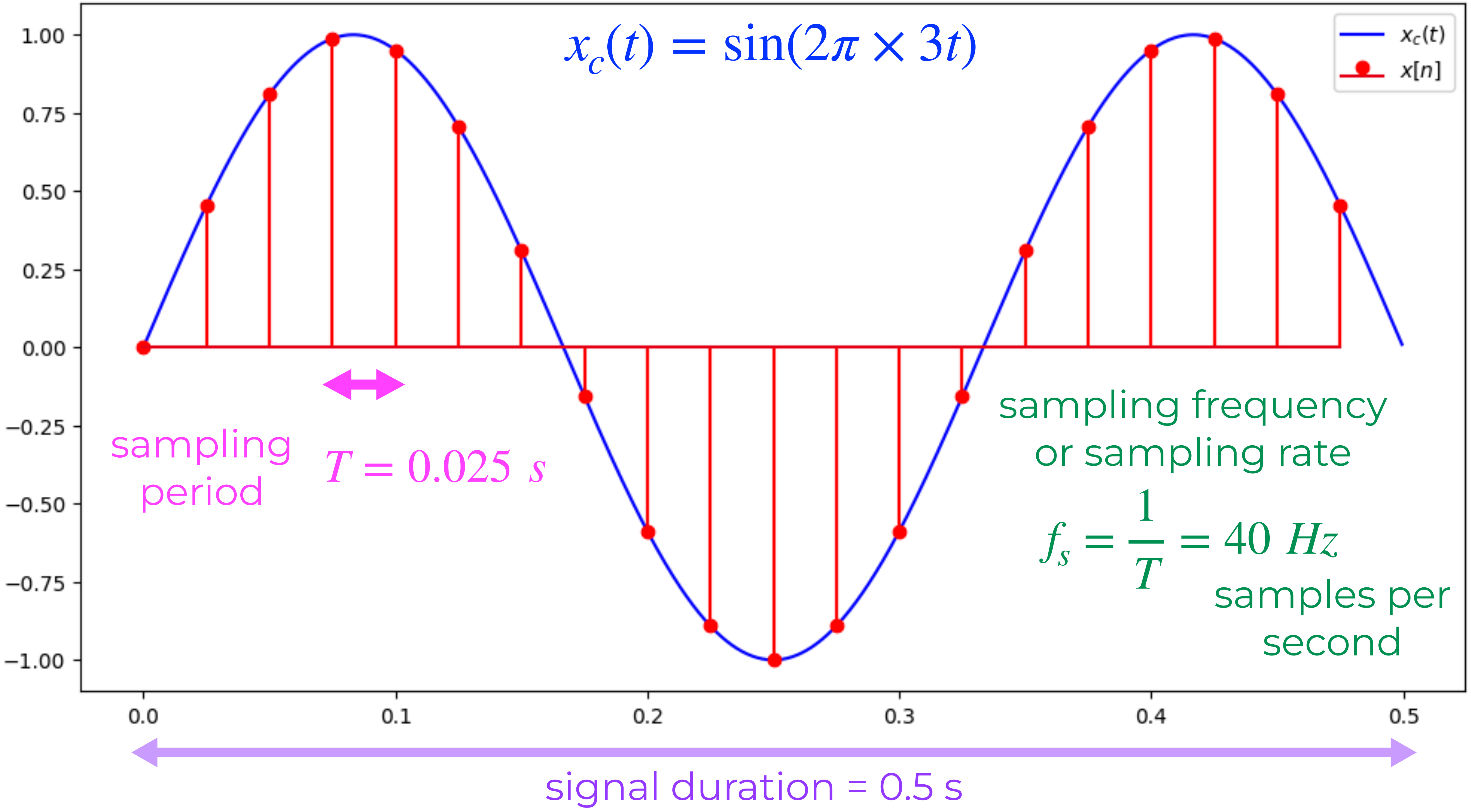
Oppenheim, Alan V. Discrete-time signal processing. Pearson Education India, 1999.

Oppenheim, Alan V., et al. Signals and systems. Vol. 2. Upper Saddle River, NJ: Prentice hall, 1997.

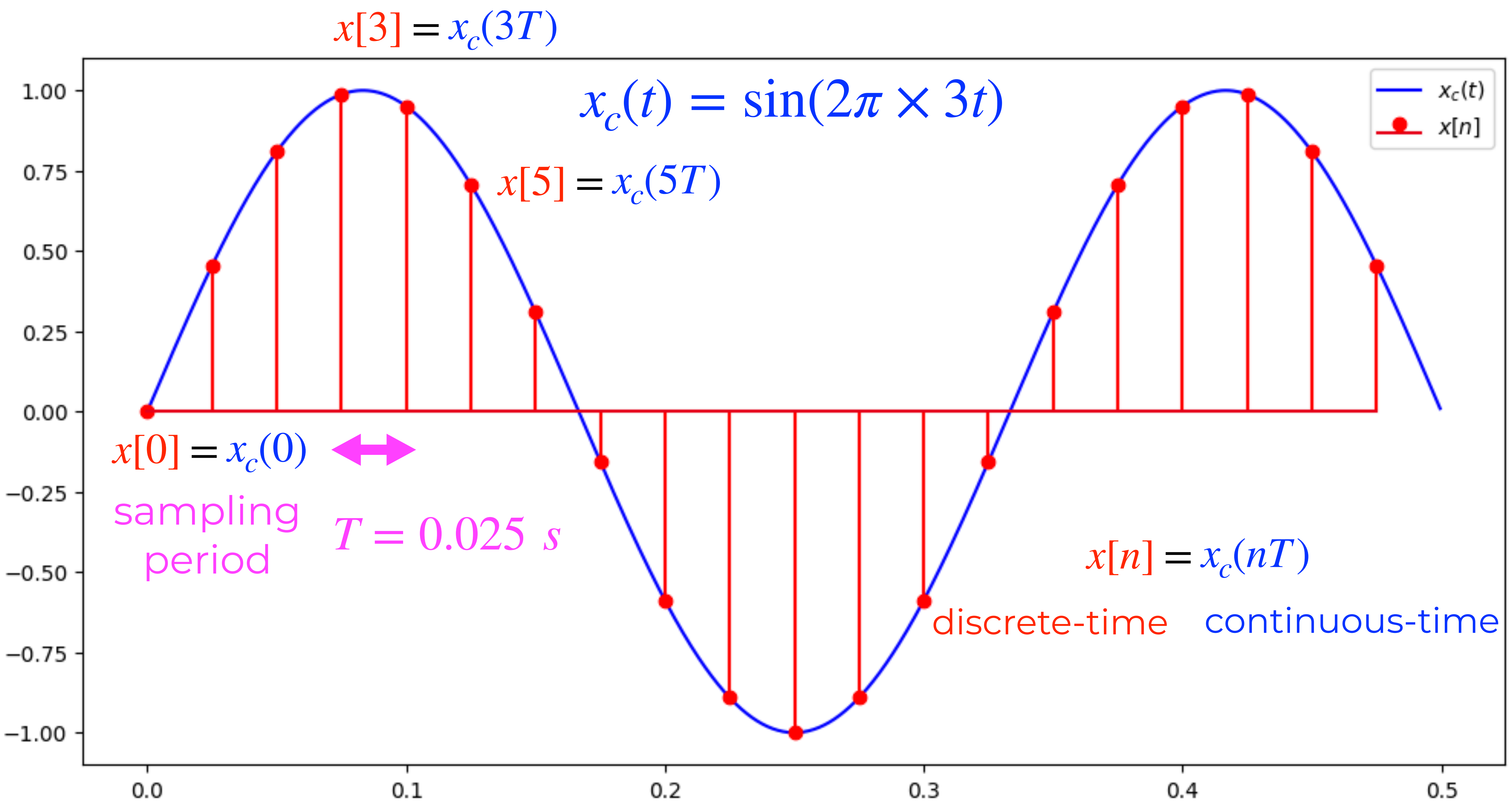
Sampling of Continuous-Time Signals



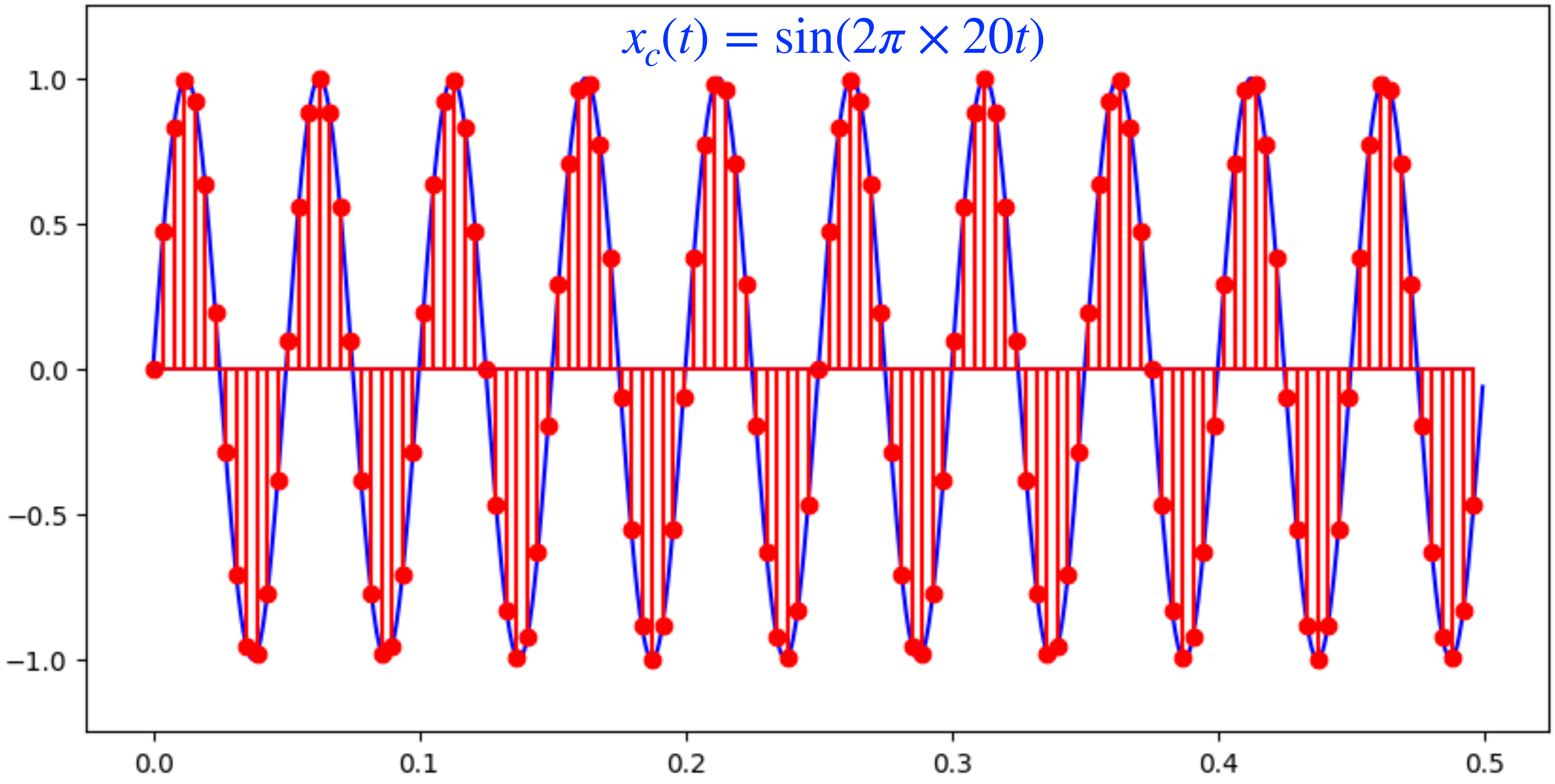
Sampling of Continuous-Time Signals



Sampling of Continuous-Time Signals

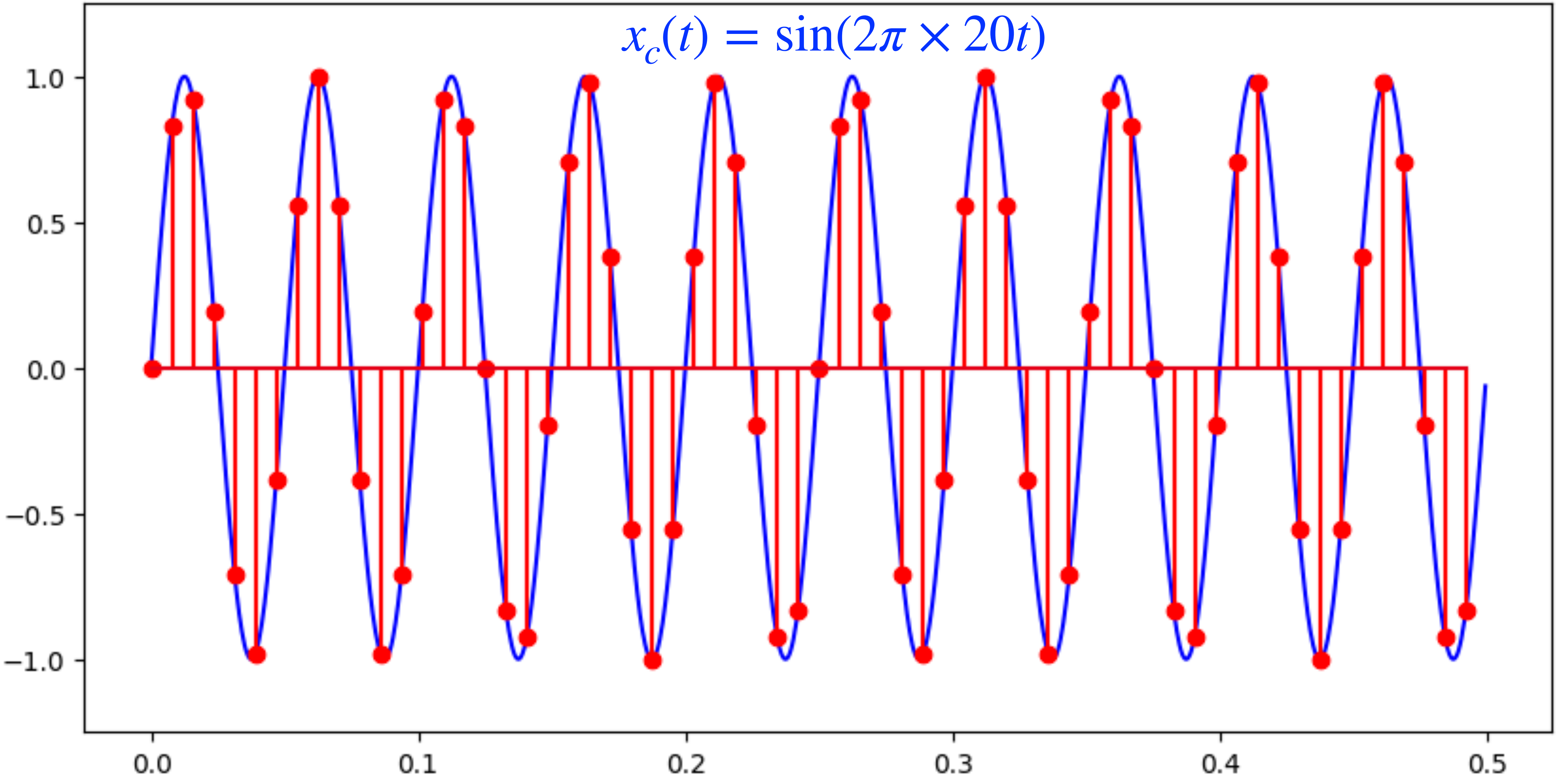


Sampling Rate



$f_s = 256\ Hz$
$T = 0.004\ s$
128 samples

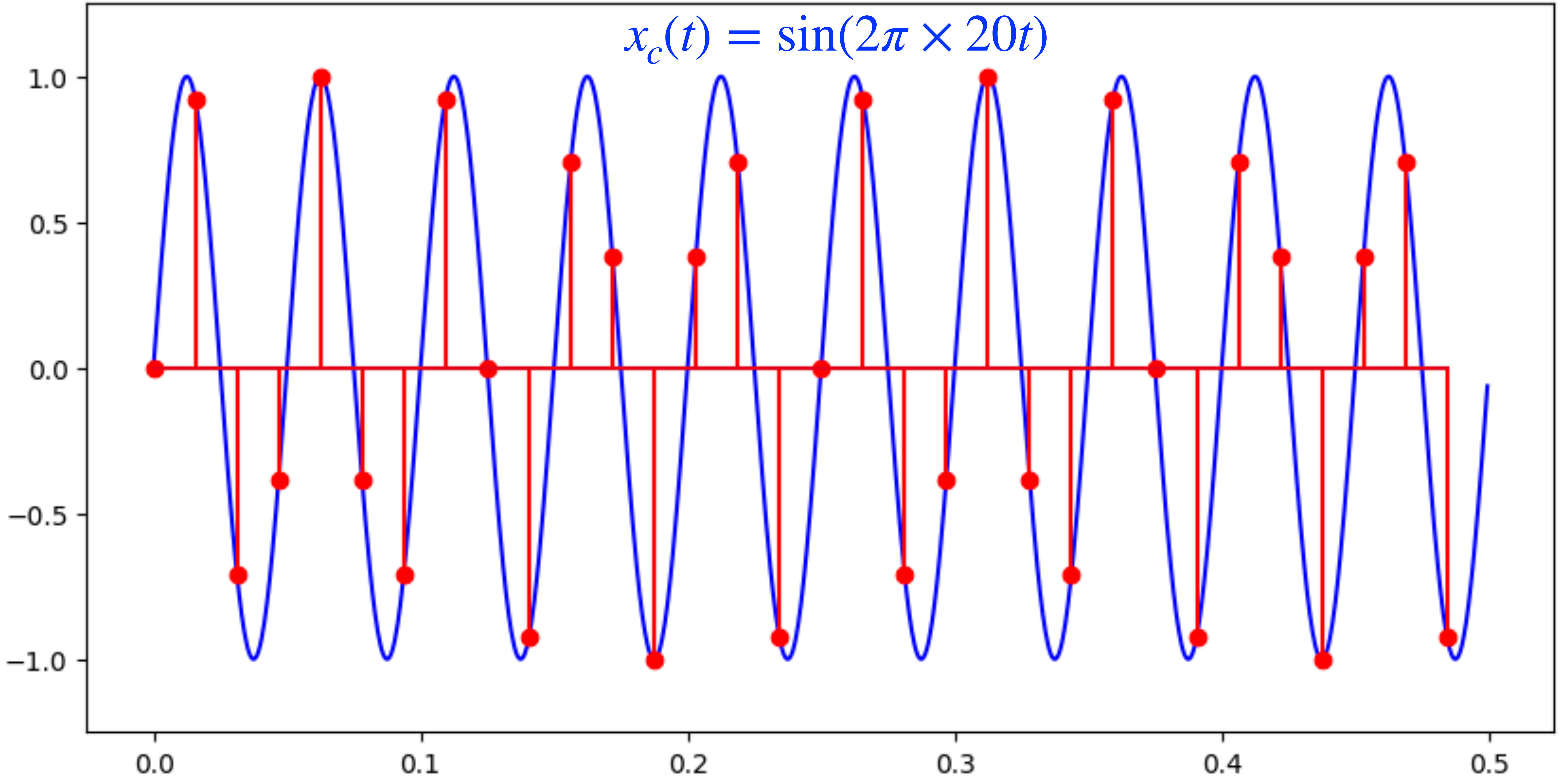
Sampling Rate



$f_s = 128\ Hz$
$T = 0.008\ s$
64 samples

Brain Code Camp

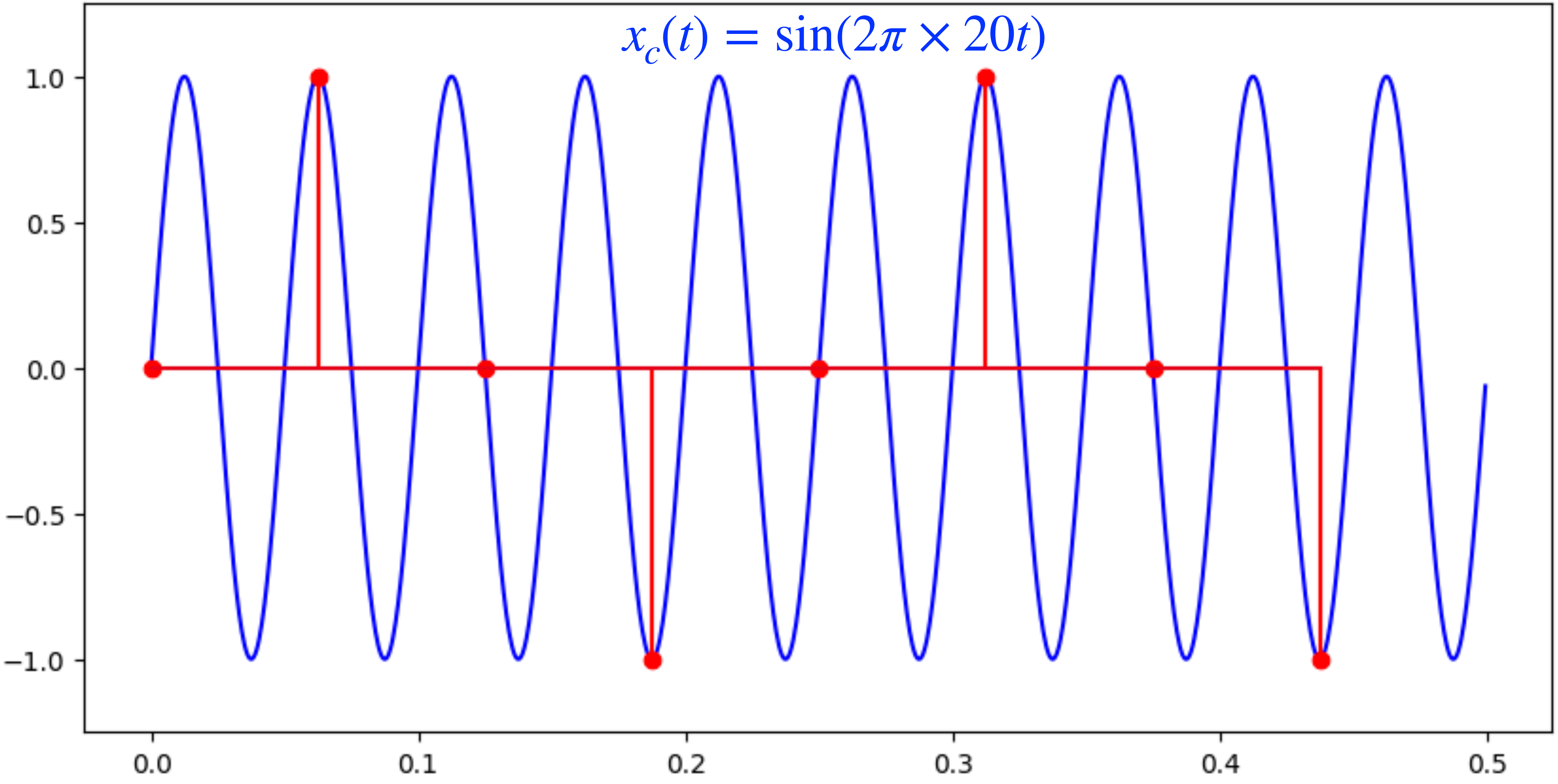
Sampling Rate



$f_s = 64\ Hz$
$T = 0.016\ s$
32 samples

Brain
Code
Camp

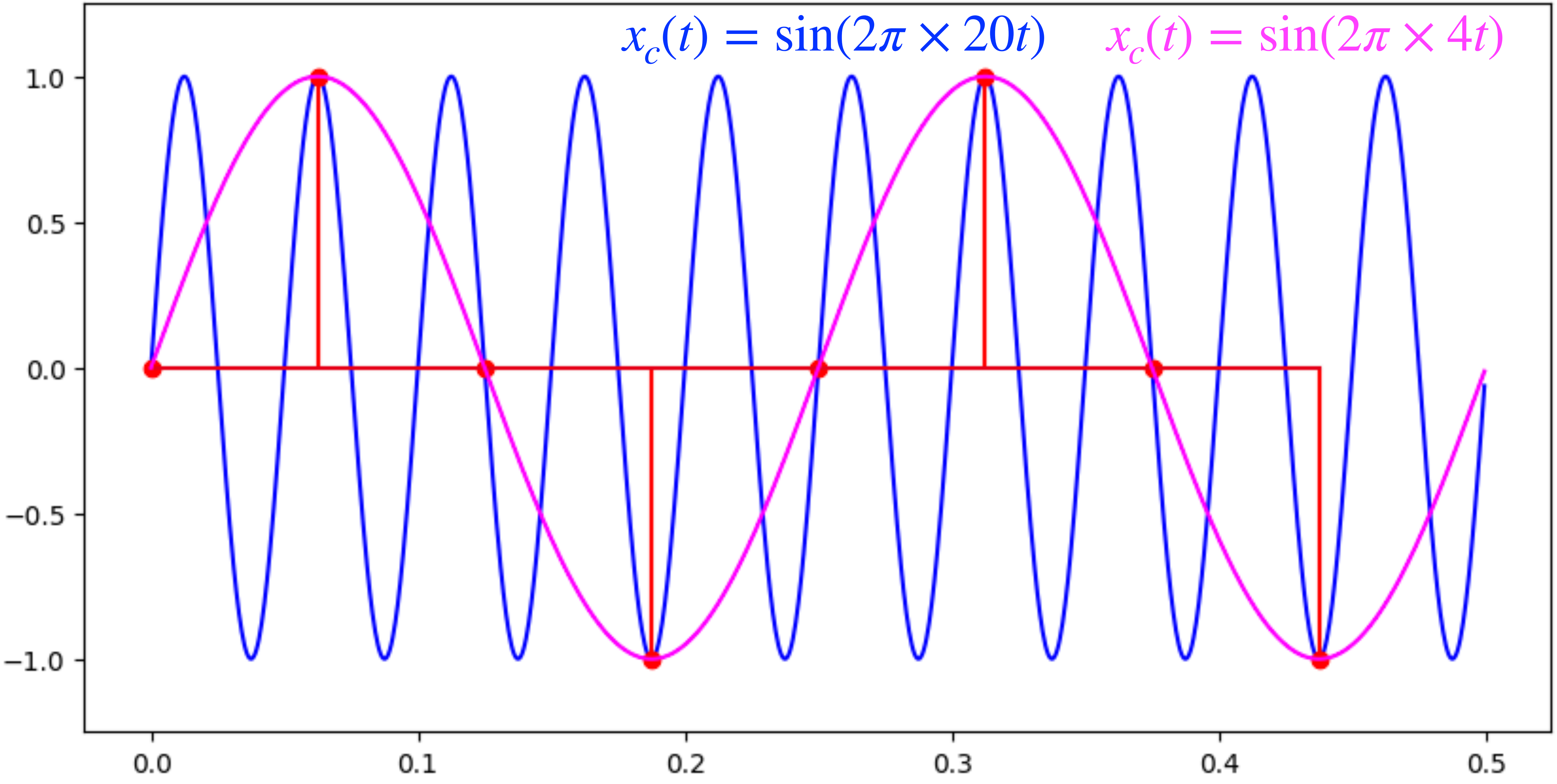
Sampling Rate



$f_s = 16\ Hz$
$T = 0.00625\ s$
8 samples

สร้างคน ข้ามพรมแดน

Sampling Rate



$f_s = 16\ Hz$
$T = 0.00625\ s$
8 samples

Brain
Code
Camp

The Sampling Theorem

Communication in the Presence of Noise*

CLAUDE E. SHANNON†, MEMBER, IRE

THEOREM 1: *If a function $f(t)$ contains no frequencies higher than W cps, it is completely determined by giving its ordinates at a series of points spaced $1/2W$ seconds apart.*

If a function $x_c(t)$ contains no frequencies higher than W Hz, then it can be completely determined from $x[n] = x_c(nT)$ if $T < \dfrac{1}{2W}$.

$$f_s = \frac{1}{T} > 2W$$

The Nyquist rate - $2W$

The Nyquist frequency - W