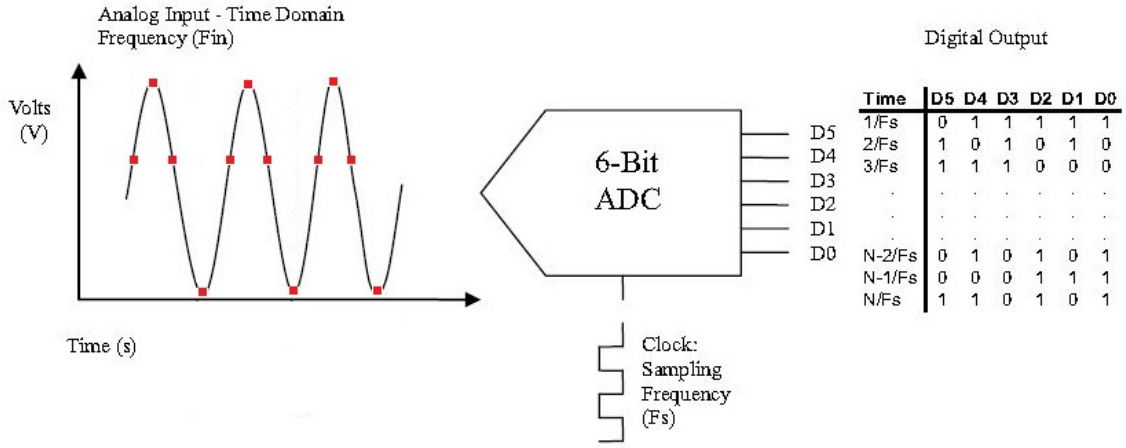
# Bandwidth vs Frequency (Subsampling Concepts)

**TIPL 4700**

**Presented & Prepared by Neeraj Gill**

# Sampling An Analog Signal

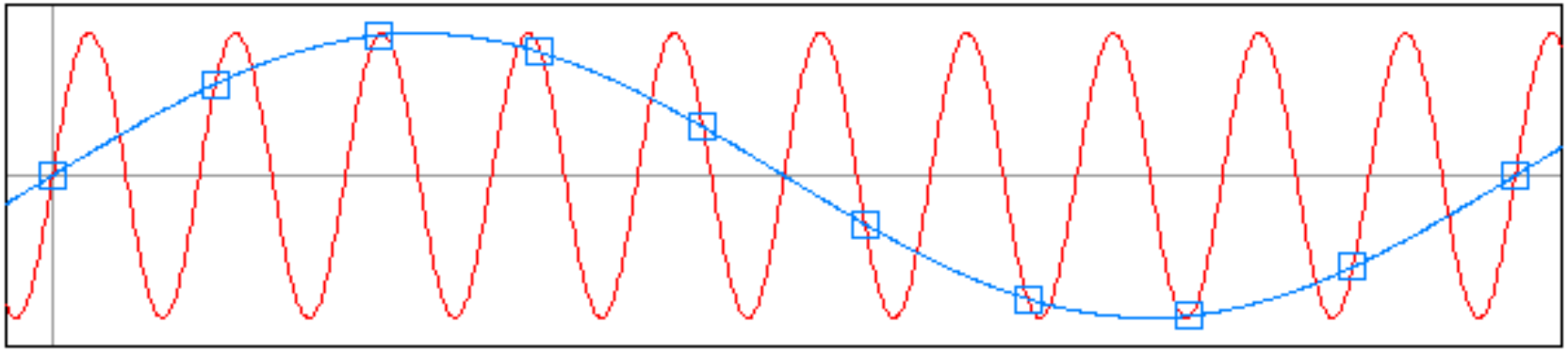
- Fin is frequency of analog input signal
- Fs is sampling frequency of ADC
- Nyquist-Shannon sampling theorem: Fin < Fs/2



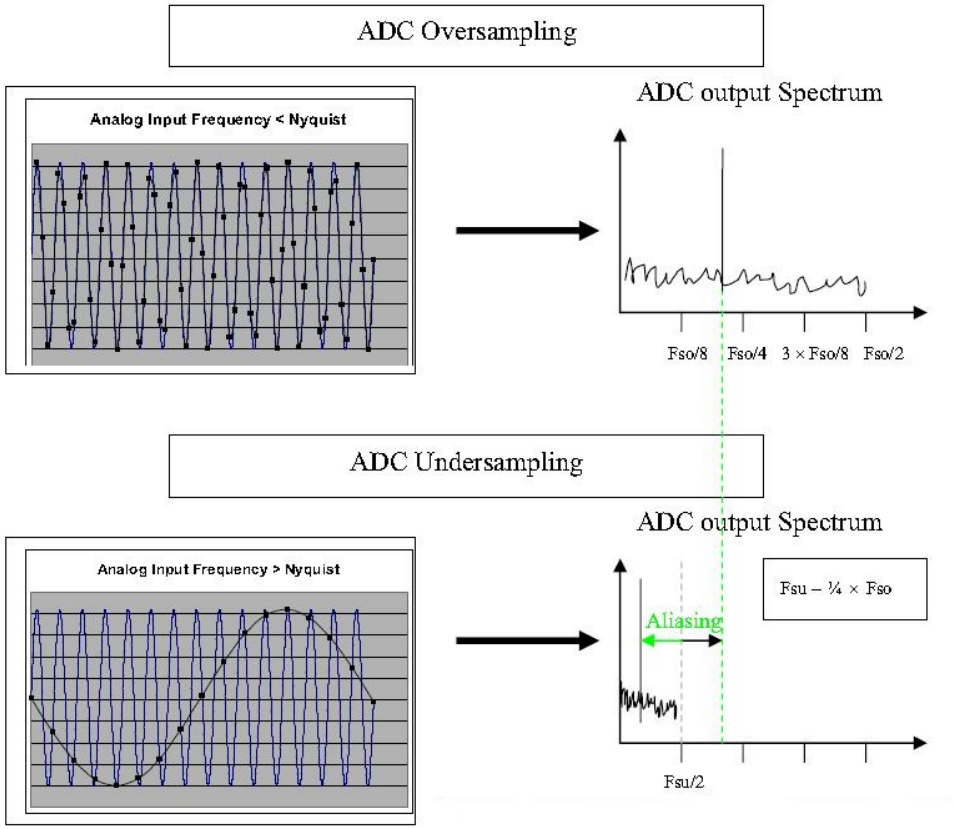

| Time | D5 | D4 | D3 | D2 | D1 | D0 |
|---|---|---|---|---|---|---|
| 1/Fs | 0 | 1 | 1 | 1 | 1 | 1 |
| 2/Fs | 1 | 0 | 1 | 0 | 1 | 0 |
| 3/Fs | 1 | 1 | 1 | 0 | 0 | 0 |
| . | . | . | . | . | . | . |
| . | . | . | . | . | . | . |
| . | . | . | . | . | . | . |
| N-2/Fs | 0 | 1 | 0 | 1 | 0 | 1 |
| N-1/Fs | 0 | 0 | 0 | 1 | 1 | 1 |
| N/Fs | 1 | 1 | 0 | 1 | 0 | 1 |

# What is Aliasing(Undersampling)?

- Aliasing - two different sinusoids give the same digital samples
  - If $F_s$ is the Sampling Frequency (clock rate)
  - a high frequency $F_{red} = 10/9 * F_s$
  - and a low frequency at $F_{blue} = 1/9 * F_s = F_{red} - F_s$
  - Both look like $1/9 * F_s$ to the ADC

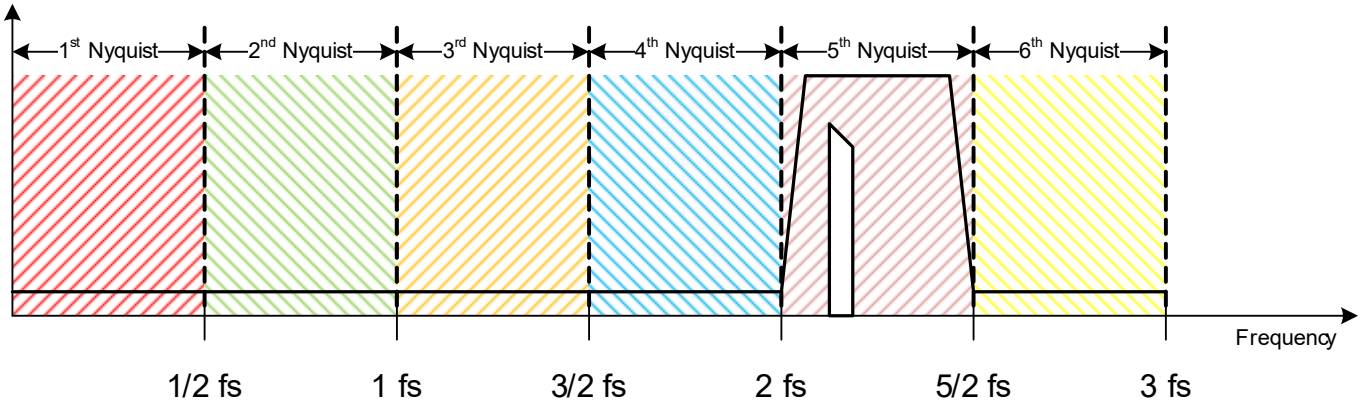


# Oversampling & Undersampling in Frequency Domain

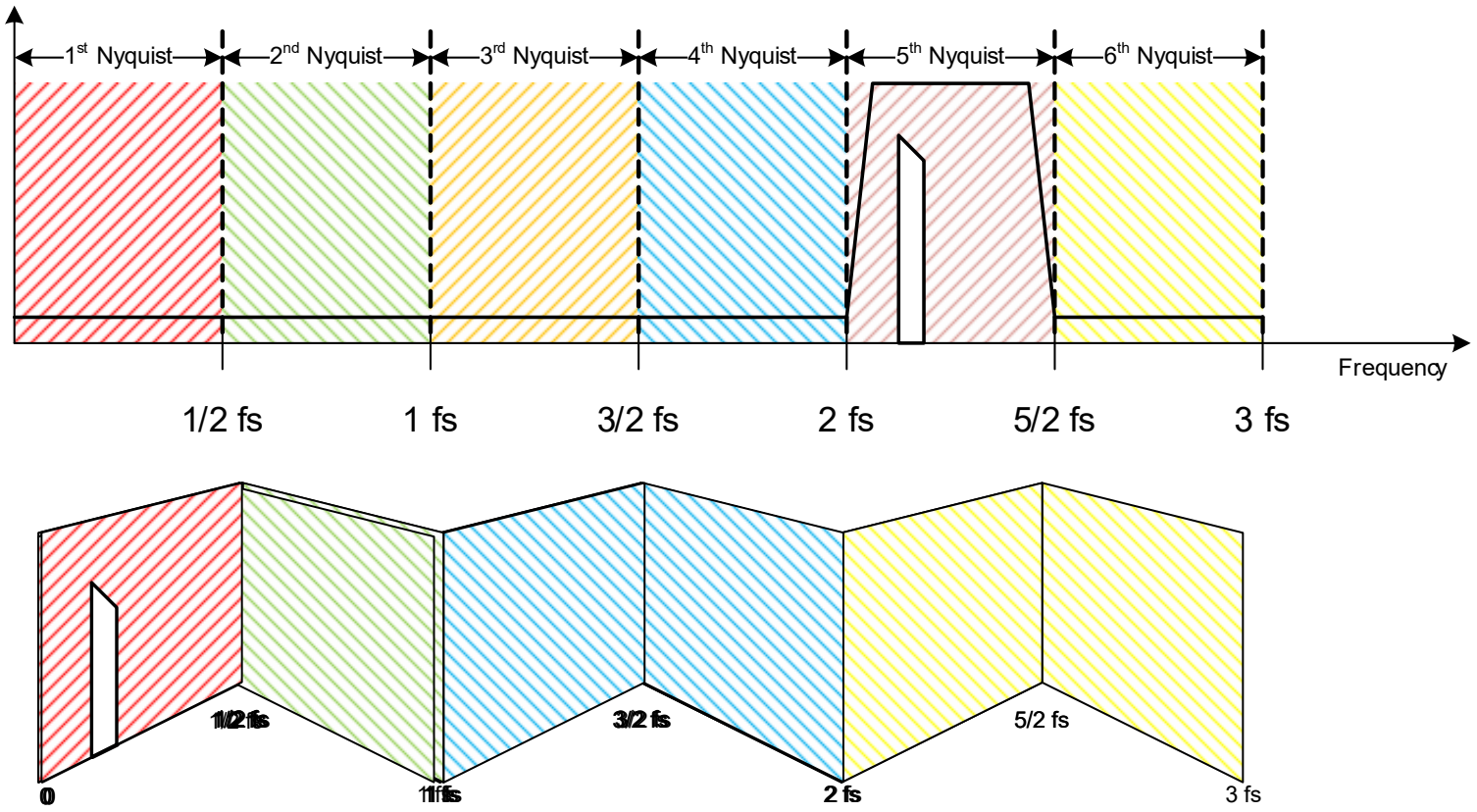


# Nyquist Zones

- When talking about High Speed Data Converters, often the term ‘NYQUIST ZONE’ is used
- One Nyquist zone has a bandwidth of half the data converters sampling frequency
  - 1st Nyquist zone: DC – 1/2 Fs
  - 2nd Nyquist zone: 1/2 Fs – 1 Fs
  - 3rd Nyquist zone: 1 Fs – 3/2 Fs
  - 4th Nyquist zone: 3/2 Fs – 2 Fs
  - And so on…



# Practical Aliasing Example - Undersampling



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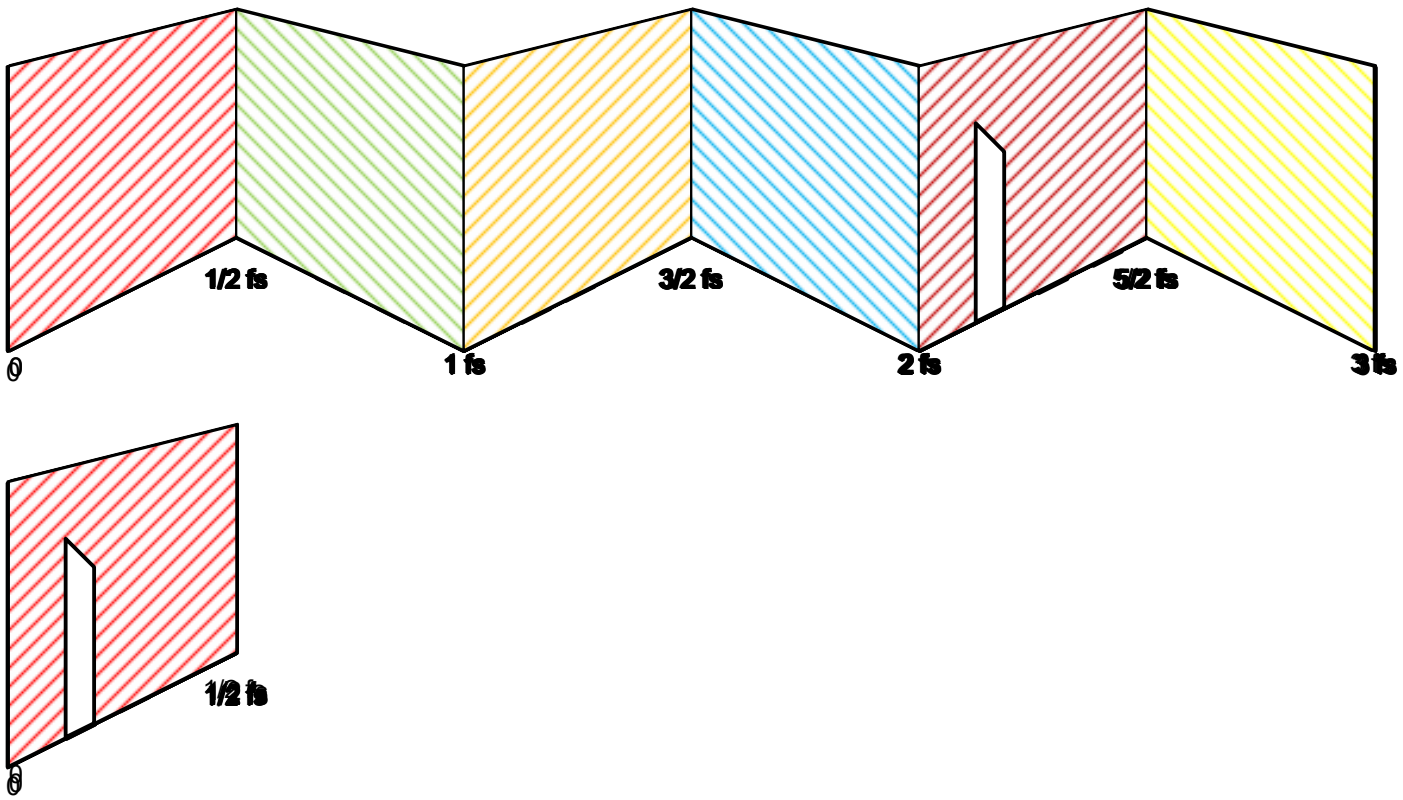
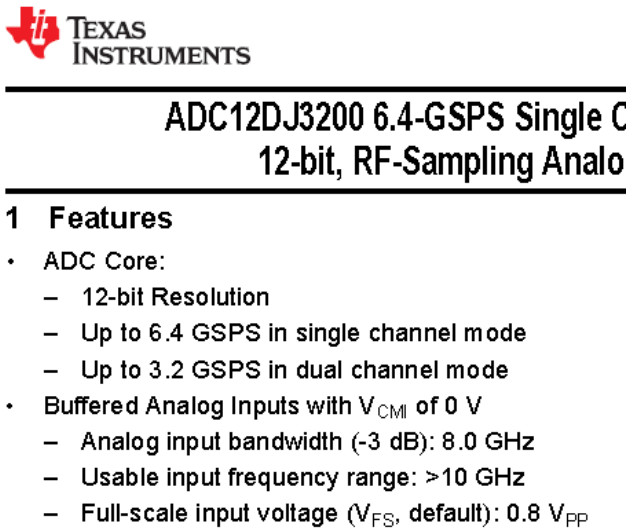


# Can all ADCs Undersample? (depends on input bandwidth)

- Analog Input Bandwidth is the analog input frequency at which the power of the fundamental is reduced by 3dB with respect to the low-frequency value
- ADC12DJ3200 (12bit, 6.4Gsps), with a 8 GHz Analog Input Bandwidth(-3dB), can sample input frequencies up to 8GHz.
- There are ADCs that cannot under-sample, which are sometimes called Nyquist Converters, and are usually high precision and a little slower



Texas Instruments

ADC12DJ3200 6.4-GSPS Single C
12-bit, RF-Sampling Analo

1 Features

- ADC Core:
  - 12-bit Resolution
  - Up to 6.4 GSPS in single channel mode
  - Up to 3.2 GSPS in dual channel mode
- Buffered Analog Inputs with $V_{CMI}$ of 0 V
  - Analog input bandwidth (-3 dB): 8.0 GHz
  - Usable input frequency range: >10 GHz
  - Full-scale input voltage ($V_{FS}$, default): 0.8 $V_{PP}$

# Thank you for your time