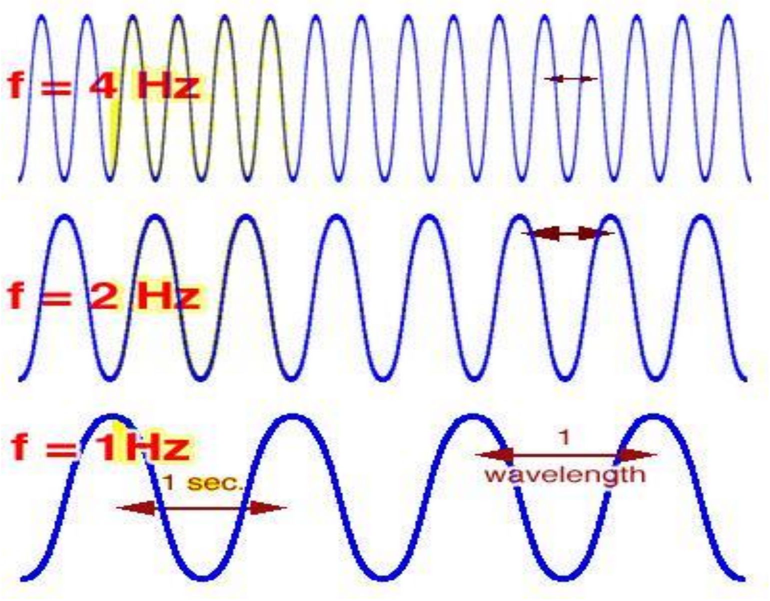
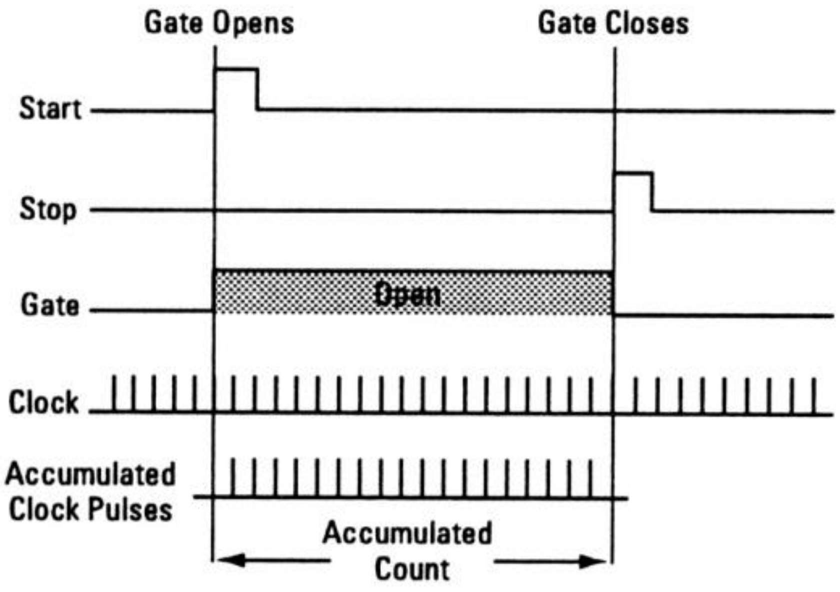
Precision Frequency and Time Measurements





The Frequency Counter

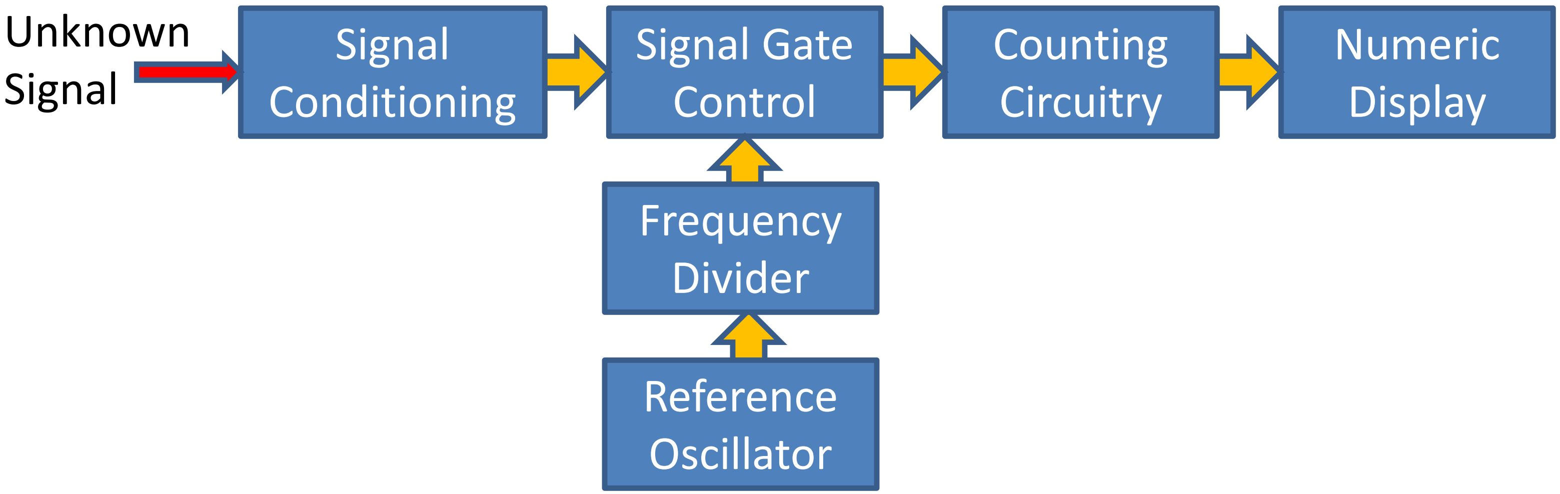
- Typically displays frequency directly from 5 to 10 digits of resolution:
  - 146.52 MHz to 146.5200000 MHz

- Measures the number of cycles a signal has over a specified time interval.
- The longer the measurement time the more resolution.

The Frequency Counter

- The measurement time (called gate time) is determined by a reference oscillator (usually a quartz crystal).
- The accuracy of the reference oscillator determines the accuracy of the mesurement which may be much less than the number of digits of resolution.

The Frequency Counter



- **The unknown signal is converted to a square wave at a known amplitude by the signal conditioning circuits.**
- **The square wave signal is passed through the gate that acts like a switch that when turned on passes the signal and when turned off blocks the signal.**
- **The gate is controlled by an accurate timing signal derived from the reference oscillator and divider.**
- **When the gate switch is open the counter circuitry accumulates the number of cycles of the incoming signal which is displayed by the numeric display.**

Accuracy vs. Resolution

- The least significant digit of the display is the resolution of the measurement. For a reading of 146,520,000.0 Hz the resolution would be 1/10 of a Hz.
- If the reference oscillator (also referred to the Time Base) had an uncertainty of 1x 10^6 (1 hertz in 1 MHz). In the above frequency example this would mean there could be a +/- 146.52 Hz error, or 1460 times worse than the .1 Hz resolution.

Accuracy vs. Resolution

- Before believing the displayed frequency you must consider the time base accuracy made up of the:
  - The accuracy of the reference used to set the time base
  - Temperature when calibrated.
  - The time since time base calibration.
  - Time Base drift rate of drift.
  - Time base sensitivity to temperature.
- Since the time base is typically a crystal it will drift over time and temperature.

Reference Oscillator Comparison

Type of Oscillator	Accuracy	notes
Simple Crystal Oscillators	.1 to 1Hz/MHz	Requires periodic recalibration
Temperature compensated crystals	.01 to 1 Hz/MHz	Requires periodic recalibration. Less sensitive to ambient temperature changes
Ovenized Oscillators	.0001 to .001 Hz/MHz	Requires periodic recalibration. Not sensitive to ambient temperature changes
Rubidium Oscillator	1 part 10^12	High Accuracy without periodic recalibration
Cesium beam oscillator	1 part in 10^14	Primary standard, no calibration required

Available Frequency Standards

- NIST WWV radio transmissions on 2.5, 5, 10, 15, 20 and 25 MHZ. (1 part in 10^7)
- NIST WWVB transmission on 60 KHz (carrier frequency based on their cesium beam frequency standards)
- GPS Satellite timing approx. 1 part in 10^10 to 1 part in 10^11. Receivers are available that sync to the GPS satellite timing signals and provide a 10 MHz output,

Is My Radio On Frequency?

- When reading a frequency counter
  - Ask what is the uncertainty of the time base?
  - What is the Drift rate of the time base?
  - When was the time base last calibrated?
  - Uncertainty of the standard used for the calibration?

Is My Radio On Frequency?

- Beware of low cost counters, they generally do not have an accurate time base.

Is My Radio On Frequency?

- Better frequency counters:



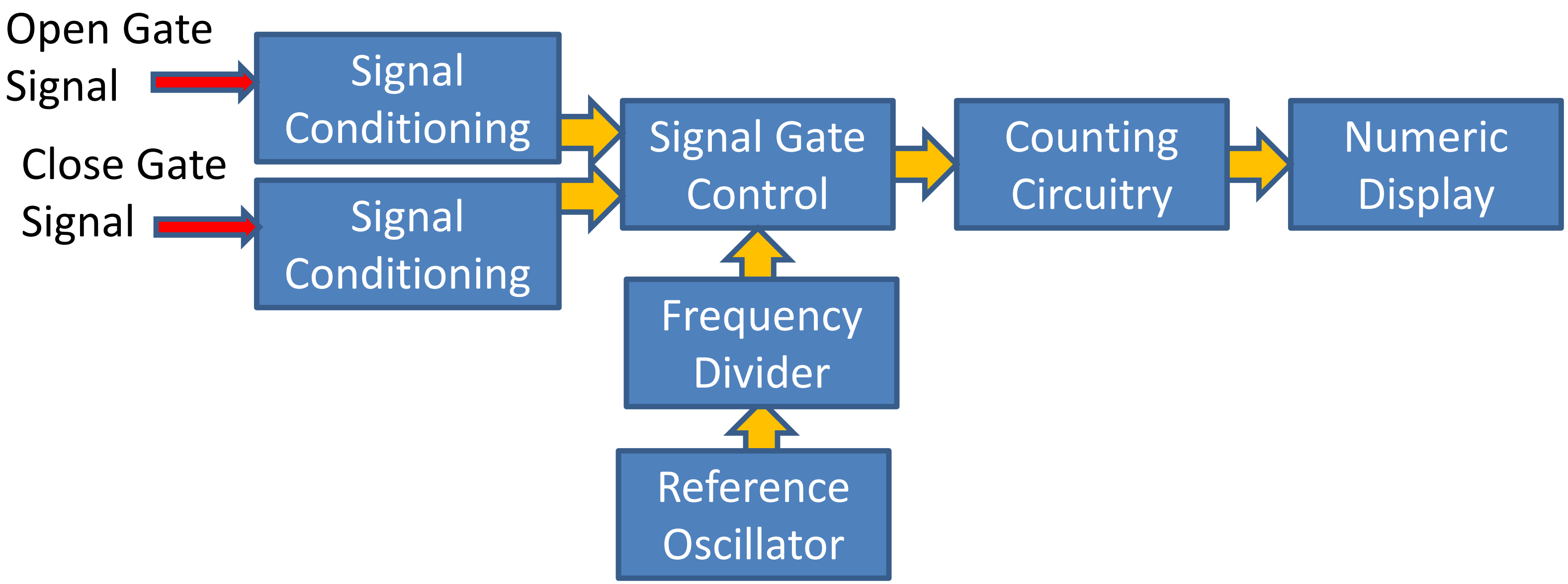



Frequency Counter Applications

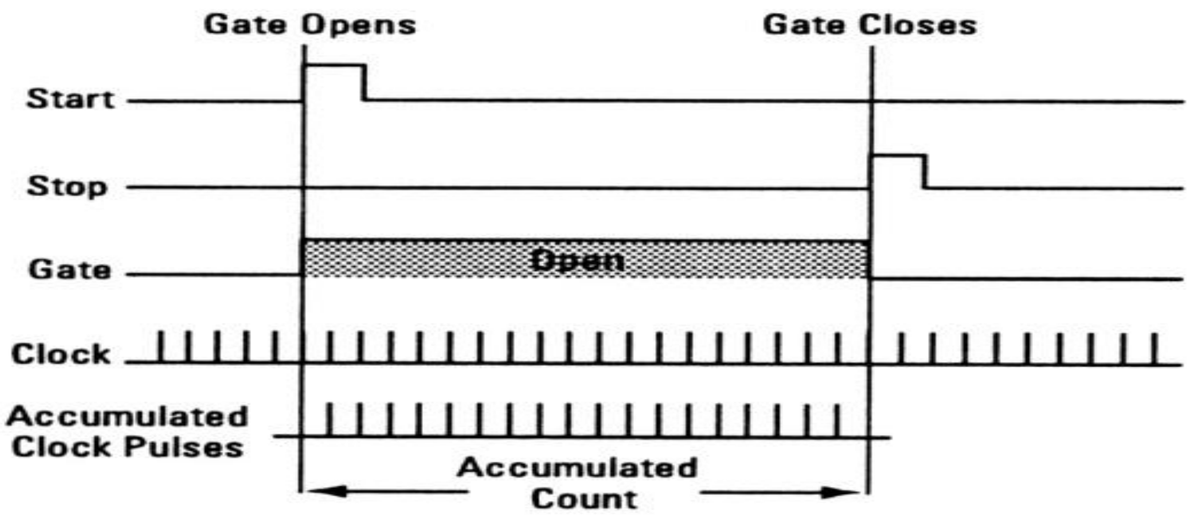
- Verifying transmitter output frequencies.
- Determining calibration points on older transceivers without digital readout.
- Verifying test instrument calibration.
- Determining unknown frequency of radios and other RF emitters.
- Tuning musical instruments.
- Digital readout for older radios.

Measuring Time Intervals

- By rearranging the functions of the counter we can measure time intervals of as little as 0.1μ second



Measuring Time Intervals



- Gate control signals can be:
  - Switch closures
  - Photo electric
  - Specific voltage levels

Measuring Time Intervals

- The time interval counter totalizes the number of cycles of the time base instead of the incoming frequency.
- Control of the gate is now from a start signal and a stop signal.
- Resolution is determined by the time base oscillator. With a 10 MHz time base the resolution is 0.1 μsecond.

Measuring Time Intervals

- Measuring low frequency signals with high resolution (also known as “Period” measurements):
  - The unknown signal is used to control the gate instead of the time base.
  - The time base is counted during the period of the gate opening.
  - A period measurement is converted to Frequency by using the formula ***Frequency= 1/Period***.

Measuring Time Intervals

- Applications for time interval measurements include:
  - Speed of a vehicle by time for a specific distance traveled (Automobiles, Snow mobiles and Pine wood derby cars)
  - Charge/discharge time for a capacitor.
  - Laboratory experiments.
  - Human reaction time demonstrations.
  - Switching times of devices such relays.
  - Setting Mechanical or electrical timers.
  - Measuring Camera shutter speed.
  - Cable and other delay times.
  - Room acoustic delay.

Any Questions?