MODULE-II

ELECTRONIC COUNTERS

Frequency Counters

Electronic counters are extensively used for measuring the frequency (number of occurrence of an
event in a given time), time period of an event and time interval between two events. Most digital
voltmeters generate a time-interval related to the level of the input voltage first. Then, they measure
that interval and display it.

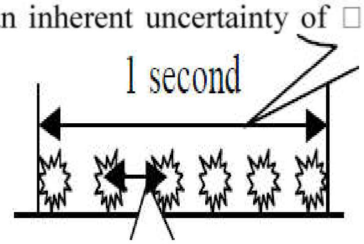
Time and Frequency Measurements

Operational Modes of Counters

Electronic counters are extensively used for measuring the frequency (number of occurrence of an event in a given time), time period of an event and time interval between two events. They display the results directly in digital forms that can be easily read by the user. The counters work in three operational modes as:

□ the frequency,
□ time-period and
□ time-interval.

The number of occurrences of event over the time of observation (i.e. 6 events per
second). All digital displays have an inherent uncertainty of □1 digit in the



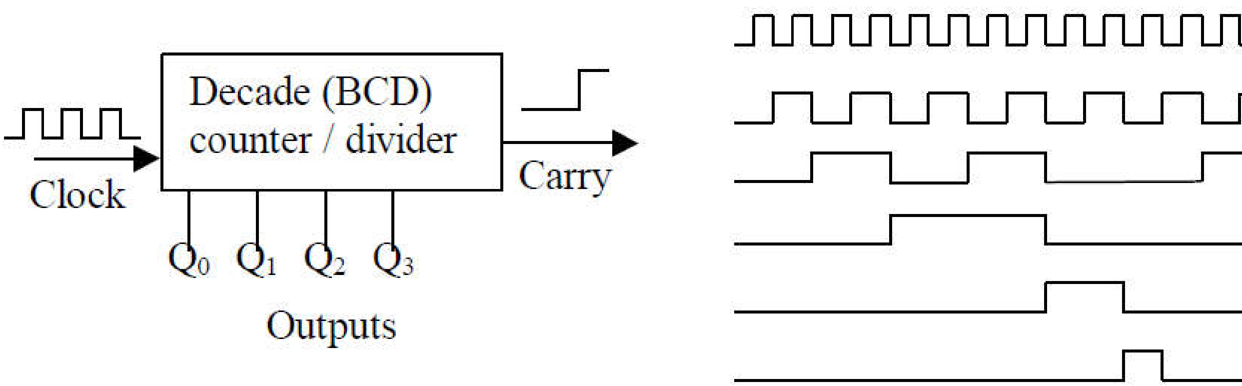
last digit of the
display. If the number displayed is small, this uncertainty causes large reading errors. Therefore, this mode is useful at high frequencies The inverse of the time-period (i.e. one explosion every 100 millisecond). This is useful at low frequencies. Some counters automatically switch to this mode as the low frequency ranges are selected. The period is measured and inverted usually by digital techniques and the displayed result is the frequency. New counters contain microprocessors that perform this operation easily.

Following elements are common in all modes of counters:
The magnitude of the input signal is not important. The periodic input signal is converted into a pulse sequence by the signal shaper, which is composed of a comparator and a pulse generator. Here, AC/DC coupling, trigger level and polarity settings are available as in the case of the oscilloscope. There is no amplitude range selection except a divide by ten (20 dB) attenuator to reduce the amplitude of the input signal to a safe level for high-amplitude inputs.

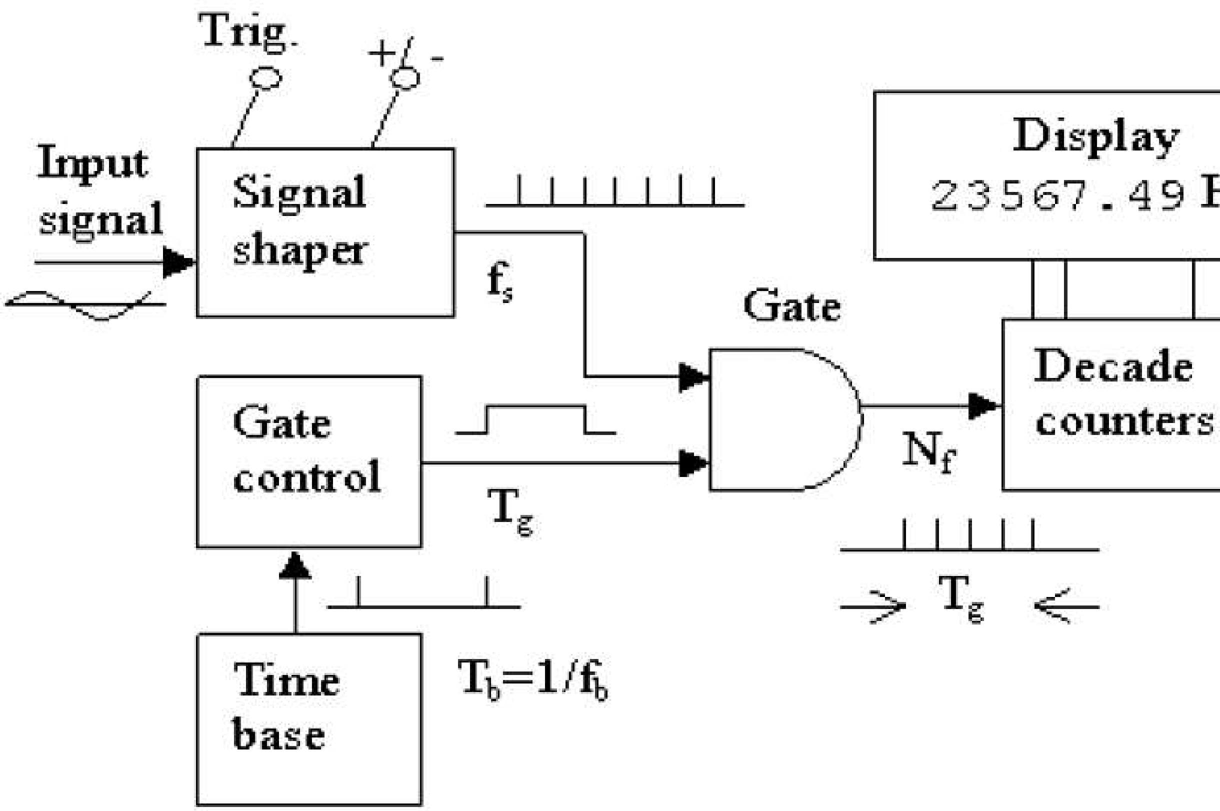
□ All measurements are related to the timing information coming from an internal time-base. Therefore, a very stable time base is an essential element of the counter. Calibration of the time-base circuits may be achieved by using special frequency standards based on tuning forks, crystal oscillators or with NBS (National Broadcasting Society) standard broadcast frequencies.

□ A control gate sets the duration of the counting and refresh rate (the frequency of repeating the measurement).

□ They mostly use 7-segment light emitting diode (led) or liquid crystal (lcd) type displays. Depending upon the frequency range of operation, there may be six to eight digits displayed. Decimal counters are used to accumulate (count) incoming pulses from the pulse gate and generate a binary coded decimal (BCD) code at the output as illustrated in Figure. The code ranges from 0000 to 1001 corresponding to decimal “0” and “9” incrementing with every input pulse. With the 10th pulse, the code returns to 0000 and the counter provides a carry pulse to the next stage. At the end of the counting session, the code accumulated in the
counters is transferred to a digital latch that holds it until the end of the next counting
session. Counters are cleared automatically after the data is transferred to the latch. The user can also clear them during initialization. This code stored in the latch is applied to the display through BCD to 7-segment decoders and displayed as decimal numbers. The display also incorporates annotations for the time units (□s, ms, and s) and frequency units (Hz, kHz, and MHz). The time-base and/or gate control switches set the position of the decimal point.



The Counter in Frequency Mode



Block diagram of the counter in frequency mode

Principle of Operation

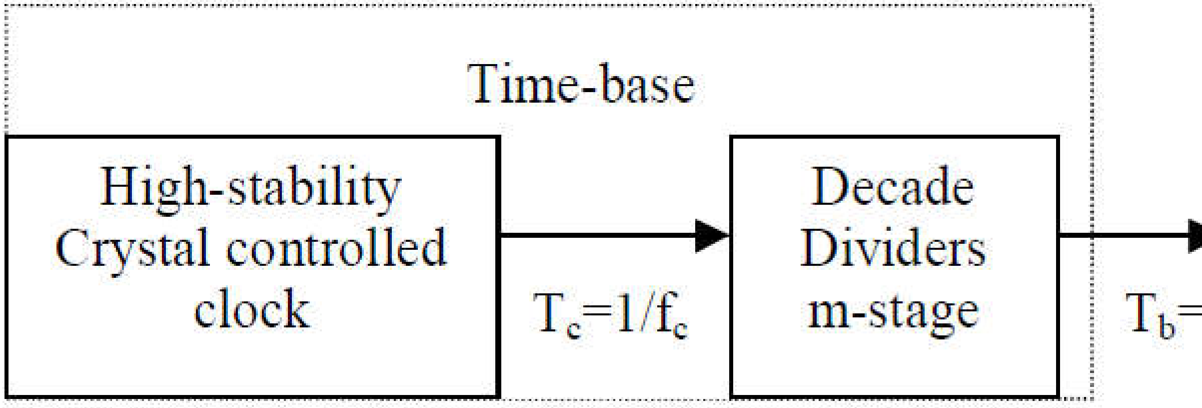
Figure shows the block diagram of a counter set to the frequency mode of operation. The timebase
circuitry provides the start and stop pulses for the pulse gate. The pulses generated from the input signal via the signal shaper are counted. The duration of the gate signal (*Tg*) is equal to the period of the time base signal (*Tb*).

Number of pulses counted $N=T_g * f_s$

f_s being frequency of the input signal. Commonly used values for T_b are 0.1 s, 1 s, and 10 s.

The Time Base

Accuracy of the measurement is directly affected by the uncertainty in gating. Hence, a time-base with high accuracy, precision and long-term stability is essential. This is managed via a high stability clock circuit that runs at frequency *fc*



Block diagram of the time-base

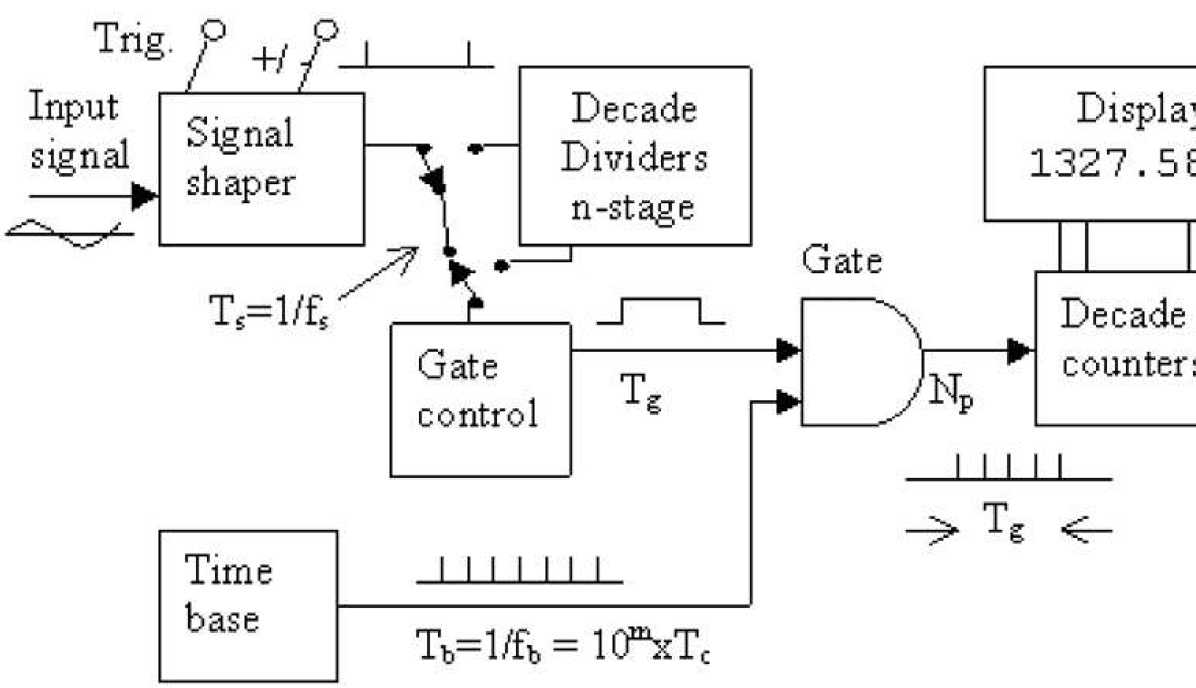
In some counters, the divider ratio is indicated at the time-base selector switch. Finally, the frequency of the input (f_s) is determined from the number displayed (N_f) and time-base setting (10_m) as:

$$f_s = \frac{N_f}{T_b} = \frac{N_f}{10^m} f_c$$

The decimal point automatically moves in between appropriate digits and respective frequency unit is also highlighted
to ease the reading as mentioned above.

The Counter in Time-Period Mode

Principle of Operation



Block diagram of the counter in time-period mode

In the period mode, the input signal provides the gating and the time-base supplies the pulses for counting as shown in Figure . The number of pulses counted:N=fb*Tg.

$$T_s = \frac{N_p}{f_c} \times 10^m$$

Hence, 10m becomes the multiplier in case of the period measurement. Period measurement is preferred to frequency measurement in determining lower frequencies. The read-out logic is designed to automatically positioned the decimal point and display the proper unit.

The Counter in Time-Interval Mode

The phase-angle (shift) between two signals may be determined by measuring the time interval between similar points on the two waveforms. Figure 4.40 illustrates the principle diagram of the measuring set-up. Both inputs contain signal shapers that generate pulses corresponding to the trigger pick-off. One of the pulse controls the starting of the counting while the other one stops the counting. Trigger levels and slopes may be different for both channels. A common-separate switch (Cm / Sep) allows utilization of the same signal for both channels and with different trigger settings; the time between sections of the same waveform can be measured. This is especially important in determining the pulse duration and rise-time of the signal.

HARMONIC DISTORTION ANALYZERS

22·28. Introduction. Another measurement which provides information on the wa of an alternating voltage or current is the harmonic distortion This type of measurement is testing of amplifiers and networks as to what extent they distort the input signal.

A measure of the distortion represented by a particular harmonic is simply the amplitude of harmonic to that of fundamental. Harmonic distortion (HD) is then represente

$$D_2 = \frac{E_2}{E_1},\ D_3 = \frac{E_3}{E_1},\ D_4 = \frac{E_4}{E_1}$$

where D_n (n=2, 3, 4......) represents the distortion of nth harmonic and E_n represents the am of nth harmonic. E_1 is the amplitude of the fundamental.

The total harmonic distortion or distortion factor is defined as

$$D = \sqrt{D_2^2 + D_3^2 + D_4^2 + \ldots\ldots} = \frac{\sqrt{E_2^2 + E_3^2 + E_4^2 \ldots\ldots}}{E_1}$$

Percentage harmonic distortion

$$= \sqrt{D_2^2 + D_3^2 + D_4^2 + \ldots} \times 100 = \frac{\sqrt{E_2^2 + E_3^2 + E_4^2 + \ldots}}{E_1} \times 100$$

The harmonic distortion can be computed from the measurements of wave anal
described earlier. However instruments are available whereby the distortion can b
directly.

22·29. Distortion Meters. These instruments operate on the principle of firs
the rms value of the total wave (fundamental plus harmonics) and then removing the f
component by means of a highly selective filter circuit and measuring the rms value of
only. A block diagram of a distortion meter of this type is shown in Fig. 22·23. F
value of the total wave is measured with selector switch in position 1 and the circuit is
that the meter reads 100%. The selector switch is then put to position 2. This cuts

which rejects the fundamental frequency component, and meter reads the rms value of the
only. Thus the meter indicates the precentage distortion directly.

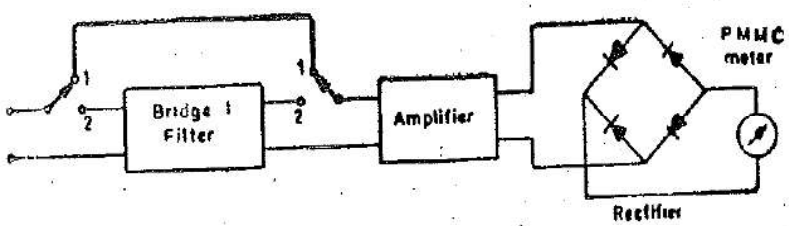


Fig. 22·23. Harmonic distortion meters.

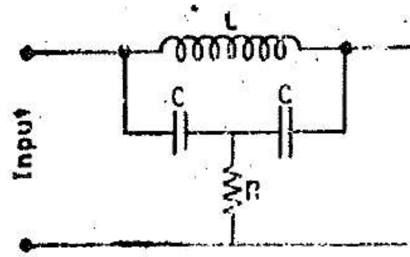


Fig. 22·24. Bridge '*T*' Filter circu

A '*T*' bridge circuit is commonly employed to reject the fundamental freque
circuit is shown in Fig. 22·24.

It can be shown that if the circuit is tuned to the fundamental frequency of $f_0=1/2\pi$
and R is adjusted to satisfy the relation $R=Q_L X_L/4$.

where $Q_L=X_L/R_L$ with R_L=resistance of inductor, the attenuation of fundamental
components is infinite under these conditions.

SPECTRUM ANALYZERS

22·30. Introduction. Spectrum analysis is defined as the study of energy distribu the frequency spectrum of a given electrical signal. The study gives valuable informa bandwidth, effects of different types of modulation and spurious signal generation. The of the above quantities and phenomena are useful in the design and testing of radio frequenc pulse circuitry.

The spectrum analysis is divided into two major categories on account of instr limitations and capabilities. They are : (*i*) Audio frequency (AF) analysis, and (*ii*) Radi (RF) spectrum analysis. The RF spectrum analysis covers a frequency range of 10 MHz and hence is more important, because it includes the vast majority of communication, radar, and industrial instrumentation frequency bands.

The spectrum analyzers are sophisticated instruments which are capable of graphically the amplitude as a function of frequency in a portion of RF spectrum. These find wide applications for measurement of attenuation, FM deviation, and freque in puls

22·30·1. Basic Spectrum Analyzer. The basic spectrum analyzer is designed t graphically, a plot of amplitude versus frequency of a selected portion of the frequency spec study. The modern spectrum analyzer basically consists of a narrow band superheterody and a CRO. The receiver is electronically tuned by varying the frequency of the local

Signal Acquisition in a Spectrum Analyzer

Most spectrum analyzers (including the models in lab) are heterodyne spectrum analyzers (also called scanning spectrum analyzers). A heterodyne analyzer is essentially a radio receiver (a very sensitive and selective reciever). Radio receivers, including those based on the heterodyne , will be covered later in lecture. For now we will provide a simple description of the basic ideas. Given a voltage signal x(t), we need to somehow extract the frequency content out of it. As we know, the digital storage oscilloscope provides one solution as it can calculate the FFT of the signal from stored samples. Another solution would be to pass x(t) through a long series of very narrow bandpass filters, having adjacent passbands, and then plot the amplitudes of the filter outputs. That is, if filter 1 has passband f1 - BW/2 < f < f1 + BW/2, and filter 2 has passband f 2 -BW/2 < f < f2 + BW/2, where f1 + BW/2 = f2 - BW/2, and so on, and if BW (the bandwidth) is small enough, then the filter outputs give us the frequency components X(f1), X(f 2), . . . and so on . This is, of course, not a practical solution. A better solution is suggested by a simple property of Fourier transforms: recall that if we multiply (in the time domain) a signal by a sinusoid, the spectrum of the signal is shifted in frequency by an amount equal to the frequency the sinusoid.

Now instead of a bank of narrow filters, we shall have one narrow filter centered at a fixed frequency, say fI, and we shall scan the signal spectrum across this filter by multiplying x(t) by a sinusoid of varying frequency f0 . See Figure 1. The filter is a narrow bandpass filter at a fixed frequency, fI, (called the intermediate frequency); in a spectrum

analyzer, its bandwidth is selected by the user. The oscillator frequency, f0, is adjustable, as indicated in Figure 1. In an ordinary AM or FM radio, when you tune the receiver you are selecting this frequency so that the signal will pass through the filter; in a spectrum analyzer, this frequency is automatically scanned (repeatedly) over a range, which must be selected so that the frequency component X(f) is shifted to fI and passed by the filter. For example, if we want to view the frequency content of x(t) from f1 to f2 , then we must select f0 to scan from f1 + fI to f2 + fI.