Electrical Measurement And Electronic Instruments

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Lecture - 62
Digital frequency meter

Welcome, we are studying Digital frequency meter.

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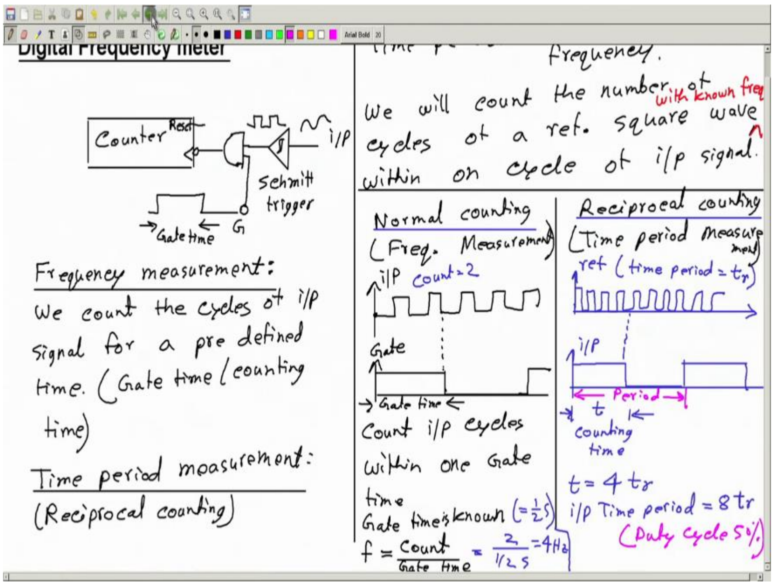

So, far we have seen that a frequency meter is nothing but a counter ok; it is basically a counter and you give the input signal to the clock of this counter; it can be either positive edge trigger or negative edge triggered. But if the input is not square or rectangular, then you have to first convert it into a square or rectangular wave.

So, you can use a Schmitt trigger ok; so, this is a Schmitt trigger. So, give the input fast to the Schmitt trigger and you feed the output here, but you can also use a AND gate so that you have a flexibility to stop the counting at some point; by making say this input G of this and gate equal to 0; you can stop passing the input from here to here, so the counting will stop ok. So, this is the input this can be a sin wave or anything, here we have a square wave and this will come.

Then ok; we may need a reset input to reset the counter value to all 0 before we start counting ok; this is the basic scheme. Now, let us talk about time period measurement ok. So, previously we have talked about frequency measurement ok, where we count the edges of the input or the receipt input edges of input signal for a predefined time and that predefined time is controlled by this gate signal ok. So, here you give a signal like this which is 1 for some time and then it is 0.

So, this is the interval where the counting occurs; so this is this predefined time which we call the gate time ok, so let me write gate time. So, this pre-defined time is called gate time you can also called is counting time ok. So, we count this signal or the pulses of this signal within this gate time. Now, let us talk about time period measurement this is also called reciprocal counting ok; so this is also called reciprocal counting why? Because, firstly you know that time period is reciprocal of frequency ok; so time period is 1 over frequency.

So, that is why it is called reciprocal counting and what do we do here? We will count the number of cycles of a known frequency signal or a reference signal of a reference signal difference square wave within one cycle of input signal ok. So, here we count the; let us write cycles in frequency measurement, we count the number of cycles of input signal within a predefined time and here instead of counting the input signal, we count another signal a reference signal with known frequency.

So, we count another see different reference signal within one time period of the input signal; so referring square wave with known frequency ok. So, let me draw the two things side by side to make it clearer. So, normal counting versus reciprocal counting ok; so in this case we measured frequency; frequency measurement and here we measure time period ok. So, what we do; we have in either cases we have two signals here this is say input signal and we so this is input and we have another signal which you call the gate or G.

This is ON for a time and then it is OFF; like this ok, in this case you count the number of cycles of this signal within this one cycle or half cycle of this gate signal. So, count input cycles within one gate pulse; I mean gate cycle or gate time whatever you call which is this ok; so this is gate time ok. So, within this you count the number.

So, in this case the count is how much? So, starting from here I have 1 cycle, 2 cycle ok. So, roughly; so I have 2 cycles of input signal within this. Now, I need to know this gate time gate time is known. So, therefore I can write this frequency f = 2 divided by gate time gate time ok. If say gate time is equal to let us take this is equal to half second or say 2 second or say half second ok; in this case count is equal to 2, 1, 2; so count is equal to 2.

So, frequency will be 2 / 0.5 = 4 Hertz ok; this is normal counting and what do we do in reciprocal counting? In reciprocal counting, let this be the input signal, this is input ok; we will have a reference signal which is of much higher frequency unknown frequency like this say its frequency is known or its; so its time period is known. So, say time period is equal to t r r for reference ok.

So, this reference signal has a time period of t r and we will count the number of these cycles within say this time ok. So, this is counting time and here say we have 1, 2, 3, 4 roughly 4 cycles of the reference signal within this half cycle of the input signal ok. So that means, this time ok; so this time is how much? If I call this t then t; I can write this is equal to 4 times t r 1, 2, 3, 4. So, this is equal to 4; so 1, 2, 3, 4 it is slightly less than 4; it is not complete cycle or maybe ye ok. So, and what will be the time period of the input signal?

So, for this; so input time period is therefore, equal to 8 times t r; as you mean that the duty cycle is 50 50; that means, this is 50 percent of the total period the period from here to here. So, this is the; so from this is one time period right and if; so if this if you assume that duty cycle 50 percent; that means, this time is same as this time so if I have 4 counts here. So, I will have; obviously, 4 counts here. So, then I can say the time period is 8 t r where t r is the known time period of the reference signal.

So, this is the difference between normal counting and in reciprocal counting. In normal counting we count the input signal within the on time of gate signal and here we count the reference signal within this on time of input signal opposite ok; that is why it is called reciprocal counting and you may ask what if the input signal is not of 50 percent duty cycle ok? So, this is a small interesting question.

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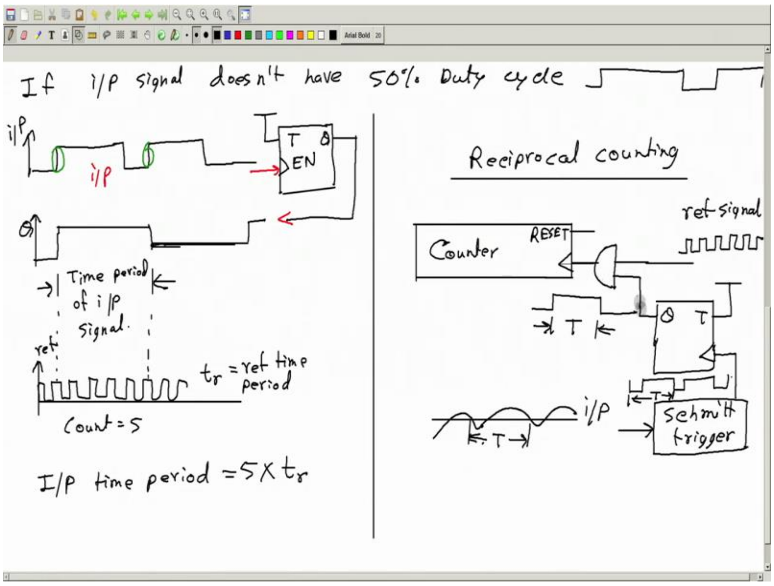

If input signal does not have 50 percent duty cycle ok; it is like this say long on time and short of time ok. So, then we cannot simply multiply by a factor of 2 and get the time period.

So, what can we do? The trick is simple then you take this input signal and pass it through flip flop like this. So, let us take a tip flip flop with toggle set to 1 and here you give the input to the enable ok. So, this signal you give this input you give to the enable. Now how to happen? How the output will look like? The output Q; Q will change every at every rising edge right, this is a positive edge triggered flip flop. So, at every rising edge; Q will change.

So, if I draw Q here on the same axis ok. So, see Q will change from 0 to 1 here at this rising edge, then it will change here at the next rising edge. So, Q will change like this 1, 0 like and so on ok. So, this is Q, this is input. So, now you see the on time of Q is same as the time period of the input signal ok. So, this is time period of input signal ok. So, for one time period it will remain on and for the next time period it will remain off ok; so it is like this ok.

So, therefore, if I use this Q as and measure the number of reference cycles ok. So, if this is my reference signal which should be of much higher frequency. So, now, you count the number of reference signals within this time ok. So, how many do you have? 1, 2, 3, 4, 5. So, count is equal to 5 and if this time period is tr; this is reference time period, then input time period is how much? Same as this, which is same as 5 counts of the different signal; so 5 times t r ok.

So, we can use our flip flop like this before; before this input I mean; so this input will be passed through this flip flop and then we can use it ok. So, in this case; if I draw it schematically; so I will have this counter and it will have this reset input to make it 0 initially. And of course, this clock this is most important, but now it will count not the input signal; it will count the reference signal.

So, here; so I will have this reference signal this is the reference signal reference square wave of much higher frequency than the input signal which will come here. But you have to have the mechanism of stopping it; so I need this AND gate ok. So, I put this and gate here and the other input of the AND gate will decide how long or for what duration the accounting should continue.

Here I will give the input signal maybe not directly maybe through this flip flop. So, Q let me draw it like this Q T; this is T which is said to level one always and here is we give the input to the clock this will be the input signal and ok.

If you have an input which is not rectangular; you may also need schematically drawing a Schmitt trigger d for this ok. So, you give the input here which can be a non-square wave like this and this is also, you see not half wave symmetric. So, therefore after this mid trigger we will have a wave form here which we look like possibly this ok. And after this we will have a wave form which will be like this; this time if it is call it T; this is same as the time period here. So, this is one time period this is T which is same as one time period here this will also be T.

So, you give first you make the input to a rectangular one; then you can use this flip flop and then within one period of the input, you count the number of cycles of this reference signal; this is how it works, this is reciprocal counting. Very much like the normal counting the only difference is the role of the input and the reference is reversed. So, here we are counting the reference signal within one period of the; input and in normal counting here we are counting this is the input receipt we are counting the input signal within one period of the gate signal. So, this two have; this two change their rules in normal and reciprocal counting ok.

Now, let us talk a bit about the errors that we may encounter in frequency measurement.

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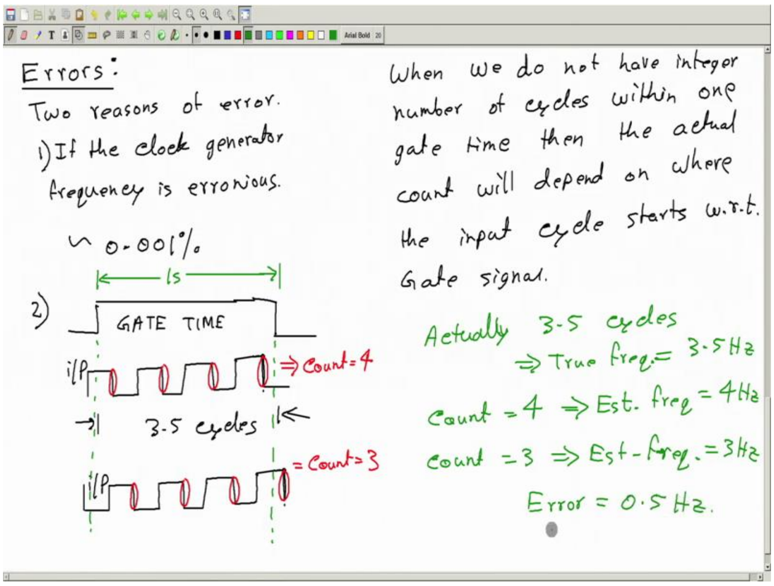

There are normally two sources of errors that I can think of. So, two reasons of error number 1, so how do we measure say frequency say in normal counting it is considered normal counting only.

So, we measure the number of input cycles within one gate time and this gate time is known to us right which need to know this gate time. But say if we do not know this gate time precisely then what will happen? We are measuring frequency with this expression right count by gate time; number of cycles by gate time.

But if gate time is not known precisely say we know this gate time to be half second, but say it is 0.49 second; in that case we will have an error right. So, and this gate signal is normally generated from a clock generator ok. So, we can have like a crystal oscillator from which we can after that this we can have a frequency divider; say this is this crystal oscillator has a frequency of 1 mega Hertz; that means, the time period is 1 micro second which is too small; now I can I will talk about frequency divider later separately.

So, say the task of this frequency divider is to simply divide the frequency of this signal. See if this is 1 mega Hertz; it may bring it down to say 1 Hertz; therefore, this time period; so the time period of the gate signal will be 1 second ok; then this time will be half second. But if this crystal oscillator is not oscillating at 1 mega Hertz, but its oscillating at a frequency of 1.000001 mega Hertz then this time will also not be half second it will be somewhat less than that. So, therefore we will have an error.

So, if the crystal oscillator or the clock generator whatever you call clock generator frequency is an erroneous. So, this could be one reason, but normally crystal oscillators are quite precise; they are the errors may be like of the order of often 0.001 percent too small ok. So, but depending on the input frequency; this may affect or may not affect. Another reason which we will talk in more detail is this; so, what we do? We do, so this is my gate time now I draw it with a larger span.

So, this is the gate time or counting time and within this time; so, this is the gate signal and within this time we measure the number of cycles of the input signal. Say the input signal is like this which has 1 period 2 periods 3 periods and so this is 1, 2, 3; see it has 3 and a half period within this time ok. So, starting from here to here we have 3.5 cycles; this is input right, and this is fed to the counter. But the counter cannot display you 3.5 because counter is always incremented by a factor of 1; by a count of 1 and say it is incremented at every positive cycle or negative cycle.

So, then the actual count that we will have in this case is 1, if it is negative edge triggered 2, 3 and is it there or not ok; it is doubtful. So, let me take two cases; let me just take two cases one case is this where I move the input signal towards the left a bit ok. So, that this starts from here therefore, this edge will also get included ok.

So, then this edge will also get included. So, this means we will have count equal to 4; you see 1, 2, 3, 4; 4 edges are within one gate cycle one gate time. Similarly, if I have the input signal starting from here at this point. So, this is the gate time then you see; this edge this edge is outside the gate time, this edge is also outside the gate time; we have three counts; 1, 2, 3.

So, we have count equal to 3 ok. So, depending on where this input start from with respect to this gate time does on which we have no control over; we can get account of 4 or count of 3 right. So, when we do not have integer number of cycles within one gate time like this; we have 3.5 cycles, not 3 cycles not 4 cycles; 3.5 cycles, then the count. Then the actual count will depend on where the input cycle starts with respect to the gate time with respect to gate signal.

So, this is gate signal with respect to this is it starting here or is it starting here depending on that; we can have 4 count or 3 counts and therefore, this will give me some error say this gate time; say this gate time is 1 second for simplicity; we actually have 3.5 cycles within this time.

So, the true frequency is; so actually we have 3.5 cycles implying true frequency is equal to 3.5 Hertz, but the count is equal to either 4; implying estimated frequency or measured frequency will be equal to 4 Hertz or the count can come out to be 3; implying estimated frequency or measured frequency equal to 3 Hertz, in this way we can have an error.

So, the error in this case; in either cases, so here also we have an error of half Hertz 0.5 Hertz here also we have an error of 0.5 Hertz; 00.5 Hertz.

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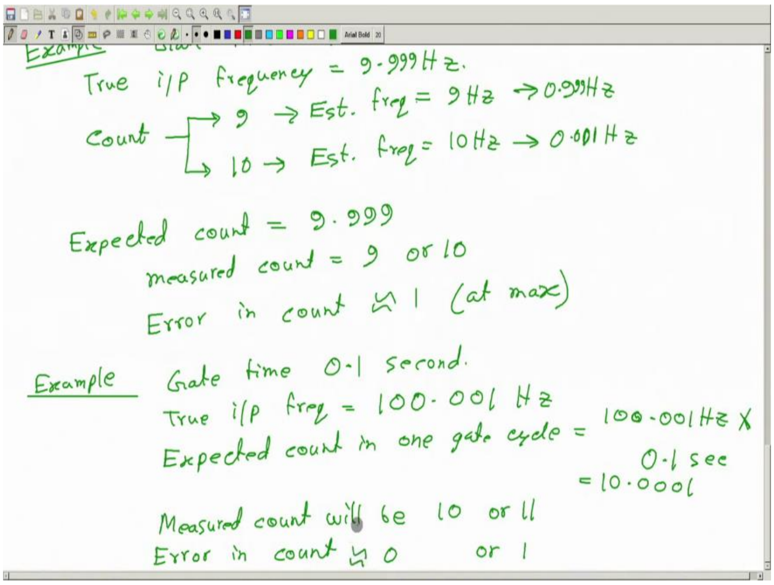

Now, let us take a case where say an example where the gate time is equal to 1 second and input frequency true input frequency is equal to say 9.9 second; 9.9 Hertz right. So, what will be the measured count? So, the count can have two possible values.

So, the count act should be within 1 second, it should have 9.9 cycles, but 9-point cycles cannot be counted we will count either 9 falling edges or 10 falling edges depending on where the input starts ok. So, in the count can be either 9 or it can be 10; if the count is 9, then what will be the estimated frequency or measured frequency; what will be our estimate?

We see 9 counting 1 second. So, estimated frequency is 9 Hertz right. In this case we see 10 counts; so we will estimate the frequency to be 10 Hertz. And in this case how much will be the error? The error will be 0.9 Hertz; 00.9 Hertz, in this case the error will be 0.1 Hertz.

So, what can be the maximum error then? The even say the maximum error could be say when you think that this is equal to 9.999 ok, the true frequency is 9.999, but the count cannot be done 999; count can be only 9 or 10. If it is 9 we will have a error estimated frequency of 9 Hertz and then the error will be 0.999 and if the count comes out to be 10, then the error will be finally, 0.001 ok.

So, in the old case we see that we can have a count value which is almost one greater than or less than from the expected count ok. So, in this case expected count; expected count was 9.999, you can put few more 9s and measured count is 9 or 10. So, error in count it is almost equal to 1; if it is 9 it, it can at max at max ok. So, at max we can have error of 1 count. Similarly, another example let me just modify the its bit. So, gate time say 0.1 second and say in true input frequency is a 100.001 Hertz.

So, how many counts do you expect in one gate time; expected count in one gate cycle is how much? This is; this is the frequency 10.001 Hertz multiply it with the time which is 0.1 second; this is this comes out to be, 10.0001, this is the expected count, but what will be the actual count? Count cannot be fraction ok. So, the measured count will be either 10 or 11. So, how much error will we have? So, error in count; so if it is 10 then the error is all very 0 almost 0; so let right it is almost 0; 0001; so that is very small 0 or ok.

Let me first write the true value and then I will do the approximation. So, this is 0.001 or 0.999 something and this two, you can approximate it as almost 0 or almost 1. So, we can always have a error of 1 count.

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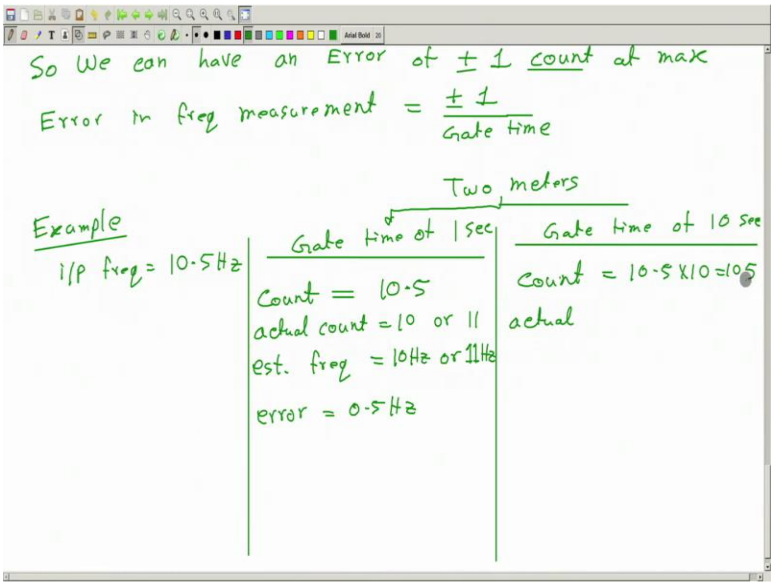

So, we can have an error of plus or minus 1 count at max ok. In the previous two examples, in the second example if the count comes out to be 11; so this is a positive error it is a like a the measured value is more 11 is greater than 10.001 and in the previous example; the expected value was 9 9.999.

But if the value comes out to be 9; then it is a negative error is measured value is less, how much? Almost by a factor by a; by an amount of 1 ok; so we can have either plus or minus 1 count at max; so this is the error that we can encounter. And then how much error we will have in frequency measurement? So, this is error in count and error in frequency measurement will be how much? This will depend on the gate time ok; that will be plus minus 1 divided by gate time because within one gate time; we can get one extra count or one less count.

So, this is the extra frequent; excess frequency measured or frequent lack, I mean the less frequency measurement. So, let us take an example say this is also interesting; let us take input frequency = 10.5 Hertz and we have two instruments ok; two frequency meters, one has a gate time of 1 second, another has a gate time of 0.1 second ok; let us take 10 second.

Now, let us compare these two instruments; so two instruments two meters; this is one, this is another. In this case, how many count do you expect? Count should be equal to 10.5; in 1 second, it should be 10.5. But actual count will be either 10 or 11; so estimated frequency is how much? If it is 10 within 1 second, then the frequency is 10 Hertz; if the count is 11 within 1 second, then it is 11 Hertz ok; this is 11.

So, error is how much? Error is like 0.5 Hertz. So, true frequency is; so this is 0.5 Hertz ok. And let us see in this case; in this case the expected count should be in 10 second how much? This multiplied by 10; 10.5 into 10 which is 105; and the actual count, this is an integer. So, it may be possible that we will get exactly this value.

But we are, but in this case one edge may lie on the; if you go back in this diagram if I will edge lies exactly on this boundary, there is a chance of missing it. So, we may still have an error.

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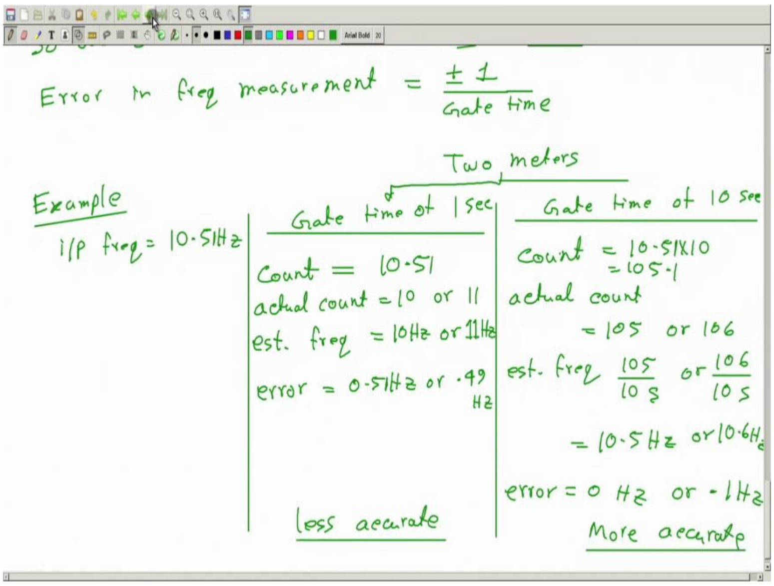

But ok; so let me change this example a bit to make it more clear let me say that this is the true frequency 10.51. So, then in this case the count should be 10.51, but it will come out to be 10 or 11.

So, estimator frequency will be 10 Hertz or 11 Hertz. So, the error will be 0.51 Hertz or 0.49 Hertz; in this case the count should be 105.1, but the actual count will be equal to 105 or 106. So, the frequency estimated will be how much?

So, here you see the maximum error is 0.1 Hertz, here you see the maximum error is 0.5 Hertz ok. So, in general this is more accurate; sorrier less accurate, this is more accurate.

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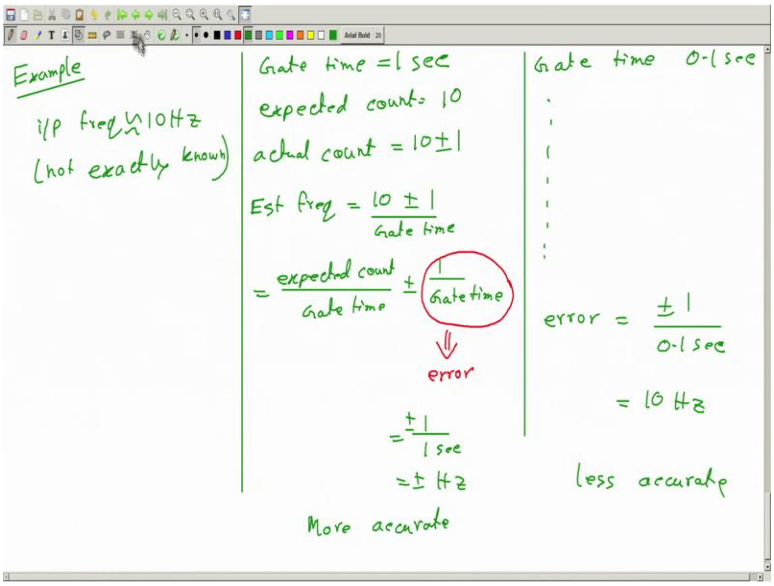

So, in general; so let us take another example say the input frequency is around 10 Hertz, but it is not known exactly; not known exactly; not exactly known. So, it can be 9.9, it can be 10; 10.1 so on, but it is around 10 Hertz. Now, if gate time = 1 second ok; then the expected count is how much? It should be 10.

But actual count; this can come out to be 1 more or 1 less ok; whether it will come more than the expected count or less than the expected come that will depend on whether this is 9.9 or 10.1 etcetera. So, we can in general have 1 extra count or 1 less count because we in this case we do not know the exact frequency. So, the estimated frequency is how much? This expected count plus minus 1 divided by gate time.

So, I can write this as expected count by gate time plus minus 1 by gate time and this is actually the error; this is the error ok. Similarly, if I use and, in this case, let me if I put the value gate time equal to 1 second ok, then this will come out to be 1 by 1 second which is plus minus 1 Hertz.

But if I have another instrument for which this is 0.1 second; then if you do this similar analysis the error will be plus minus 1/ 0.1 second, this will be equal to huge 10 Hertz. I mean the input frequency itself is 10 Hertz, we can have an error of 10 Hertz I mean 100 percent error huge; why?

Because this I mean you just see this is one tenth of a second and this one tenth of second; we have only one cycle of the input frequency. So, we will have only one edge and we can miss that edge completely right and if we miss that will estimate difficulty to be 0. So, we will have a 100 percent error ok. So, this is less accurate; this is more accurate. So, what can we say?

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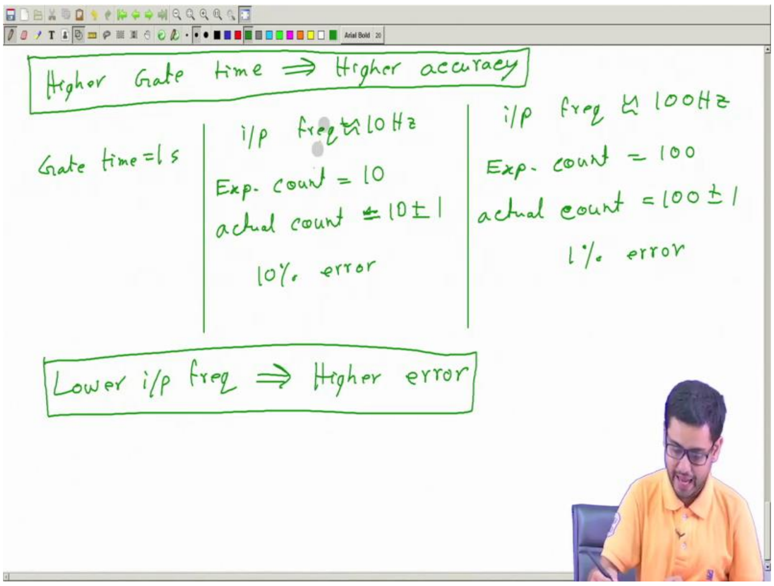

We can say higher gate time means higher accuracy; that is what we have seen in previous examples ok.

You wait for a longer time and measure the number of cycles; your accuracy in frequency measurement will be higher; that may and it also depends on the input frequency ok. Say now let us take two; two cases where I have gate time = 1 second ok, but I have two cases; input frequency equal to say 10 Hertz; around 10 Hertz and input frequency equal to around not exactly it is not known exactly, it is known around 100 Hertz.

So, here in this case we should have a count expected count within 1 second how much? 10, but true count actual count will be 10 ± 1 ok. We can miss an edge, we can have an extra edge from the next or previous cycle. In this case again expected count is around 100, but actual count will be 100 ± 1 ok. So, that means, how much you know do we have here? We have only one of; 1 out of 10 ten percent error. Here we have 1 out of 100; 1 percent error; s 10 percent error; 1 percent error right.

So, if you if you estimate the frequency here you have estimated frequency will be 9 Hertz or 11 Hertz ok. So, you will have a plus minus 1, here your estimated frequency will be 10.1 Hertz or 9.9 Hertz; so you have a 1 percent error. So, then another observation from this is that higher lower input frequency implies higher error. If the frequency of the input signal is low ok; in this case, then the chance of error is higher.

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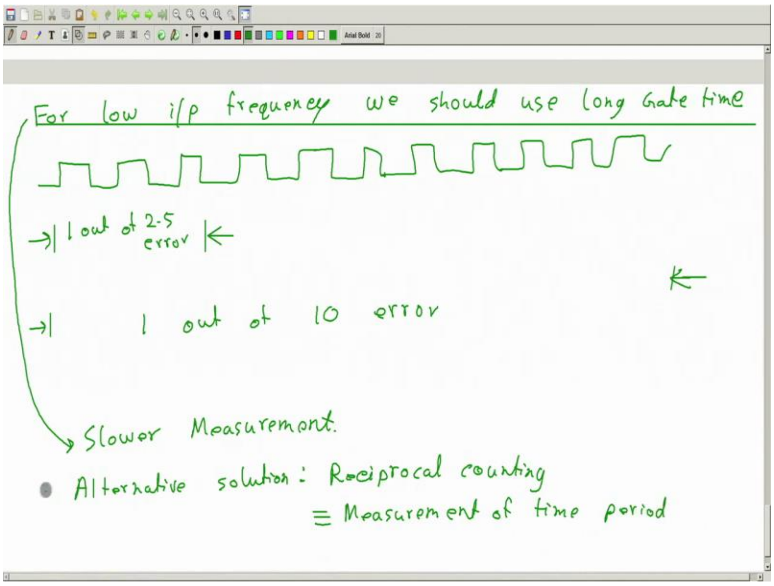

Therefore, combining these two facts; we can write for low input frequency; we should use long gate time ok.

Why? Because if the frequency is low; the error is high, but by increasing the gate time, we can increase the accuracy. So, therefore for low input frequency we need long gate time this actually means if the input frequency; if this is the input signal, then wait for a sufficiently long time I mean do not just count this much, this many only three cycles then there is a chance of having missing one cycle or having an extra cycle ok.

So, this is actually 1; 2; 2 and half cycles. So, you can get 1 extra or 1 less, but if you wait for long time or a longer time ok; like this starting from here up to here. So, you have 1, 2, 3, 4, 5, 6, 7, 8, 9, 10; almost 10 cycles if you miss 1 or gate extra. So, you your mistake is 1 out of 10. So, here 1 out of 10 error here 1 out of 2.5 is the error; so here more error; here less error. So, wait for a long time if the input frequency is low that is all to you have to do, but then what is the problem? Problem is your measurement time will be longer ok.

But this will lead to slower measurement; if you wait for a long time your accuracy will be high, but your speed will be slow ok. So, what can we do? The alternative solution is reciprocal counting which we have discussed before; which is similar to measurement of frequency; sorry measurement of time period instead of frequency ok.

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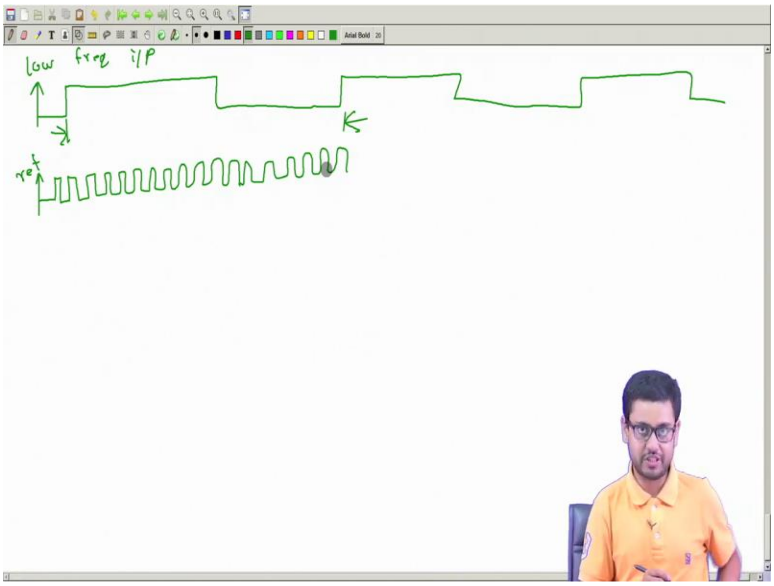

So, if my input signal is of low frequency; so this is a low frequency input ok. So, this is a low frequency input; then I can use a high frequency reference signal which is much higher of much higher frequency than this input signal ok.

And I will have enough counts in one period because this is anyway now a long time; input frequency is slow, and this is reference signal. So, I will have enough counts. So, I will have more counts and, in more counts, if I have one mistake, if I have one less counter more count out of many counts that is not too much ok.

So, therefore reciprocal counting is the solution ok. So, that is why reciprocal counting is also used; it is not only used for time period measurement, it is also used for frequency measurement indirectly if the loop; if the input frequency is low and you do not want to wait for long time. Then user use the reciprocal counting, your error will be less; you measure the time period and then take one over time period to get the frequency.

Thank you.