**Electrical Measurement And Electronic Instruments**
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**Lecture – 63**
**Linear ramp type digital voltmeter**

Welcome. Today, we are going to start a new topic, which is Digital Electronic Voltmeter.

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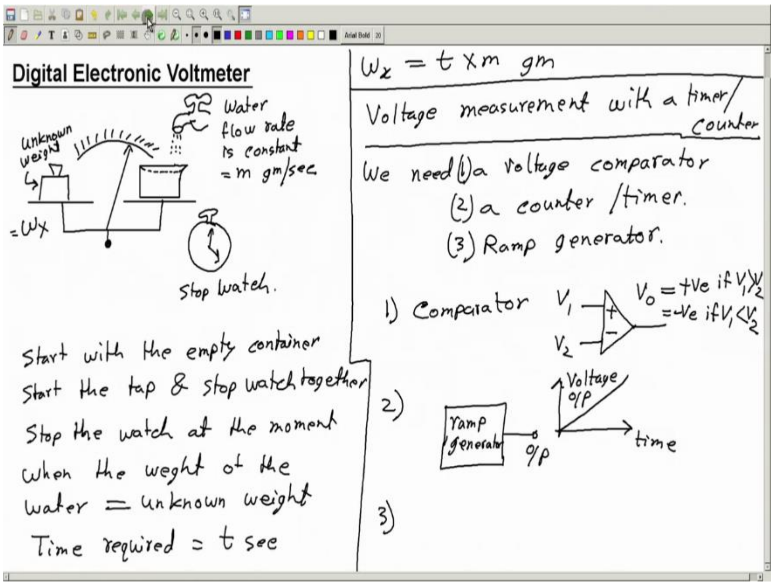


Before, we dive into that let us recall that previously we have started how to measure a frequency using a counter ok. Now, can we measure something else using a counter say like mass or weight of something with a counter? So, say we have a balance like this. So, this is a balance which 2 plates and it has a indicator. So, this is like a regular balance and where you know we put the unknown weight on one pan one plate. So, this is unknown weight.

And, on the other pan we generally we generally put a known weight and then the moment when this indicator is exactly at the middle then; that means, the unknown weight is same as the known weight, that is how we measure weight using a balance. Now, I am going to have a slightly different scheme. So, what I will do, here I will put a beaker ok. So, this is a beaker empty beaker ok. So, you can think this is a mass less beaker; beaker means it is basically a container ok. And, here I will take a tap of water ok, like this. And, the specialty about this tap is that the water flow rate is constant and known to me ok.

So, water flow rate is constant and say this is equal to m gram per second. So, the moment you turn this tap on it will start giving water at this rate and you can stop it, but you cannot change the flow rate, you can only turn it on or off and the flow rate will always be constant. Now, together with this I also have a stopwatch ok. So, let this be a stopwatch. Now, the idea is I have to measure the weight of this unknown thing, how do I do it use the stopwatch and the scheme it is simple?

So, I will start with empty container, start with the empty container or beaker and then start the tap and start the stopwatch together and the moment when so, initially it was empty. So, it was heavier ok. And, as water flows here this will go heavier and heavier and at some moment the weight of this two will be equal. And, then the pointer will be exactly at the 0 position. So, at that moment when the pointer is crossing the 0 position, I will stop the stopwatch ok.

So, stop the watch at the moment when the weight of the water is same as the weight of the is the same as the unknown weight ok. Now, if the time required for this process to happen, if is equal to time required, if this is equal to say t, then we can easily say ok, then the weight of this unknown weight call w x ok, this must be same as the total amount of water that has been stored in time t, which is same as t multiplied by m ok.

$$wx = t \times m$$

that is as simple as that ok. Now, we will use this same idea for measurement of voltage ok. So, now, let us come to voltmeter keeping this preliminary discussion in mind ok; now, voltage measurement with a timer, with a timer or counter whatever you call ok. So, what we shall do? We first need a balance like this, which can here this balance can compare 2 weights which one is heavier. Similarly, we need a instrument which can compare 2 voltages ok.

So, we need a voltage comparator ok. This is one thing that we need what else, definitely we need this counter or timer like the stopwatch a counter or timer, what else something equivalent to this tap and what would be the equivalent of this tap? So, we will need something that will increase a voltage gradually and uniformly, like this tap was increasing the weight of this beaker gradually and uniformly with time. Similarly, we need something that will generate a smoothly increasing voltage, uniformly linearly increase in voltage and that is called a ramp generator ok.

So, these are the three things we need this balance equivalent to this comparator the counter we need and equivalent to this tap we need a ramp generator ok. So, let us see then 1 by 1 number 1 comparator, what is a comparator? We have already seen it; we can use simply a op-amp ok. So, op-amp we know this acts as a comparator, simply if we just connect 2 voltages V 1 and V 2 at 2 terminals say plus and minus then the output we know, this tells us which voltage is higher ok.

So, this is a positive if this V 1 is higher, V 1 greater than V 2 and this is equal to negative if V 1 less than V 2 ok. So, this is a comparator. Now, a ramp generator I will just draw the block diagram now ok. So, this will so, this will give a output where the voltage will increase like this with time. If, this is time this is voltage or output ok. This is a ramp generator and third thing timer I do not have to say the thing. Now, how do we put them together.

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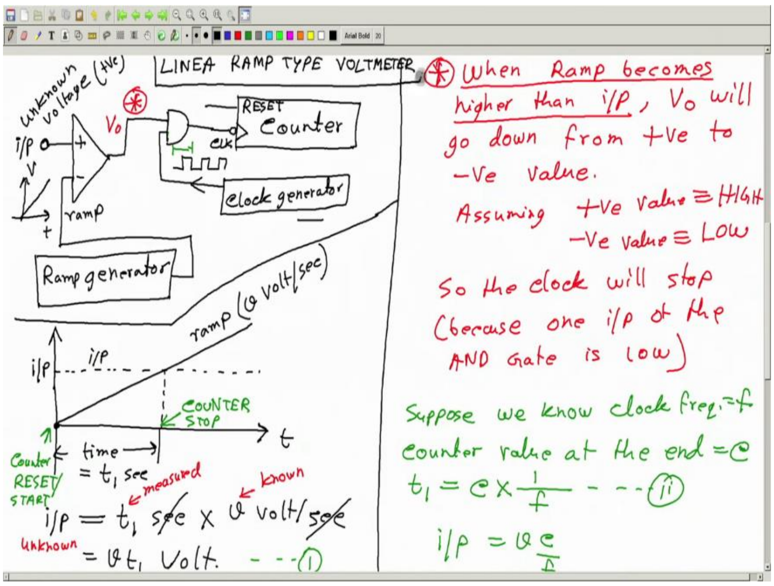


So, to put them together take the comparator plus minus so, you have to compare two things; one is the unknown voltage. So, you connect the unknown voltage here, unknown voltage, which is the input also. Here this one you connect these two the ramp generator ok. So, connect it like this.

So, this voltage will increase with time like this V versus t this will increase like this. This output now, what will be this output. This input is initially a higher than this one, because initially this is 0 assume the input to be positive ok, assume these to be positive. So, initially this is higher. So, the output will be initially high and then it will become low ok. Initially the output will be positive and then as this is increasing, then at some moment this value will become more than this value then the output will go down ok.

Now, this I will use now what I will do, I will measure the time we required for this output to go from positive to negative, which means the time required for this ramp to cross the input ok. So, call this input and this is the ramp ok. So, let me draw the timing diagram as well, let me do it on the same axis. So, this is time input is constant, input has to be kept constant. Say, the input is this is input this is input voltage ok. And, the ramp voltage is initially 0 and then it is increasing slowly linearly like this. So, this is the ramp, this is the input. Now, this is the time required for the ramp to go higher than the input cross the input ok.

Now, if this time is equal to say call it t 1 and if the slope of this ramp is a what can I say V volt per second voltage per unit time. So, this is how fast the ramp increases ok. So, this value increases at a rate of V volt per second and this is t 1 second ok. Then, what can we say about the input voltage. If, I know this time t 1 and this rate ok, then I can say that the input voltage is same as t 1 second multiplied by v volt per second same as v t 1 volt right.

So, this is this was the unknown t 1 and this v this 2 are known t 1 is measured. So, this is measured this is known we know how fast the ramp increases and this was the unknown. So, we can find the unknown by these two measured and known quantities so, now. So, what we have to do essentially, we have to measure this time required for the input to cross the this sorry required for the ramp to cross the input. So, for that we will take a counter.

Let this be a counter ok, it should have a reset input of course, so, that the counting starts from 0, we should not forget to reset the counter before the counting starts ok. So, and it should also have a clock may be positive h triggered or negative h triggered let this be the clock. And, we have to drive this with some clock generator square wave generator ok, may be some crystal oscillator or something. So, clock we need a clock generator ok. Let me put it here and then what I will do. So, I also have to make sure that, the counter is stopped the moment the ramp crosses the input. Basically, the task of the counter is to measure this time.

So, at this moment so, at this moment so, at this instant counter will be reset. So, we have to start the counter from 0 value at this moment. So, reset and start at this moment and then at this moment the counter should be stopped ok. And, then the value of the counter at this moment will indicate the time from here to here ok. So, to make sure now that the counter is stopped at this moment what I will do is simple, just like we did for a we also did it for a frequency measure we will take just a and gate.

And, this and gate gets one input from the clock generator ok. So, this is how this clock goes through the and gate and drives and increments the counter. But here I will connect this ok. So, what happens here? So, let me just put a note. So, the moment this ramp increases beyond above input, when ramp becomes higher than input voltage, then this output calls it V o, then this output then V o should will become negative will become will go down from positive to negative value.

Now, assuming that this positive value means logic high, digital logic high, and negative value is same as the digital logic low or we may need a some converted to for this to happen ok, but if this is so, then when the output goes to low or negative, then the counter will be stopped, because now this is low. So, and gate will pass only 0. So, it will not pass this count this clock ok. So, this clock will not pass through this and gate anymore ok.

So, the clock will stop because a one input of the and gate is low ok. So, the clock will stop at the moment when ramp becomes higher than the input ok. So, the clock will stop here automatically with this help of this and gate ok. And, therefore, the value of the counter at this moment will indicate the time that was required for the ramp to cross the input ok.

Now, let us do a small math, now suppose we know suppose we know the clock frequency is equal to f ok. If, clock frequency is equal to f and if counter value after the after this moment ok; after the after the ramp crosses the input ok. Let me write counter value at the end is equal to call it c c for counter, then we can write t 1 this time is how much t 1 will be counter value c multiplied by the time period of this wave ok.

Because, the counter value tells me how many clock see cycles are counted. So, if I multiply the c with the time period of this clock that will be this time t 1. So, multiplied by time period, which is same as 1 over f ok. And, from this then we can write now combine combining this, this is 1 equation and this is another equation ok.

T1 = c x $\frac{1}{f}$

i/p = v x $\frac{c}{f}$

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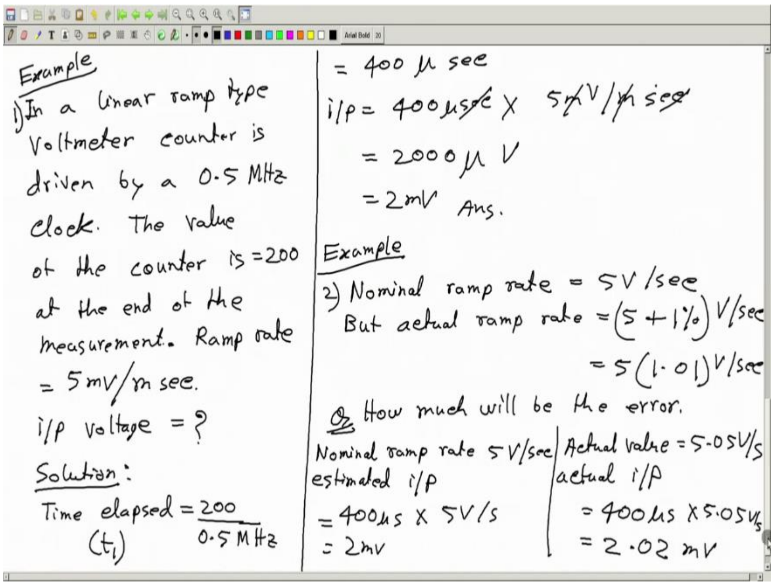


So, example suppose it is given that in a voltmeter like the one we talk before, by the way this voltmeter has a name ok. This is called a ramp type voltmeter, linear ramp type voltmeter, linear ramp type voltmeter; this is the name we can give to this digital voltmeter ok.

Now, suppose I tell you that let us say first easy example that in a voltmeter in a ramp type linear ramp type voltmeter, a the counter is driven by a say half mega Hertz clock ok. And, and the value of the counter is a say equal to 200 at the end of the measurement ok. And the ramp rate, ramp slope, say this is like say call it 5 millivolt per millisecond ok. So, these are some arbitrary numbers I am just putting. So, the question is input voltage is how much solution?

You need not remember any formula I always told you do not remember any formula just understand what is happening. So, we see that, the counter value is 200 and it is driven with a clock of 0.5 mega Hertz frequency. So; that means, what was the time required for the ramp to cross the input ok. So,

Time elapsed (t1) = 200/0.5 = 400$\mu\ sec$

i/p = 400 $\mu$ sec $x$ 5.=2 mV

Now, let us take another example or part 2 ok, part 2 of this question see the. So, the nominal ramp rate ok, this is these 5 millivolts per second or 5 volt per second ok, 5 volt millivolt per 5 per millisecond is same as 5 volt per second. But, actual ramp rate is 5 volt per second plus 1 percent say, 5 what do I mean by this. I mean that it is written on the ramp generator that it is that the slope of it is 5 millivolt per second it is written that is what I think ok.

But, actually due to manufacturing aid or due to aging or whatever the ramp rate is actually changed, it is changed to this value 5 volt per second sorry 5 5 volt per second plus 1 percent ok, which is same as a 5 multiplied by 1.01 volt per second ok. So, this is the actual value. Now, if this is the case the question is how much will be the error? ok. So, we will error we will have error why, because the name plate rating or the nominal rate value of this ramp is 5 volt per second ok.

So, nominal ramp value ramp rate is 5 volt per second, but actual value is how much this is 5.05, 5.05 volt per second ok. So, if I believe in this value, then we will estimate the unknown voltage as so, estimated input will be how much. So, just let us use this from this. So, it will become 4 400 microsecond 400 microsecond multiplied by 5 volt per second, say this is same as to millivolt per as we computed before. So, this is what we will believe the input to be we will think the input is this much, but actual input is how much?

Actual, input this will be this multiplied by 5.05 volt per second. So, you can calculate how much this is this is so, this will be I think 2.02 millivolt sorry yeah 2.0 millivolt. So, please check my calculation I do not have a calculator with me now. So, if I do any mistake please forgive me until mean the forum. But, you can do this multiplication.

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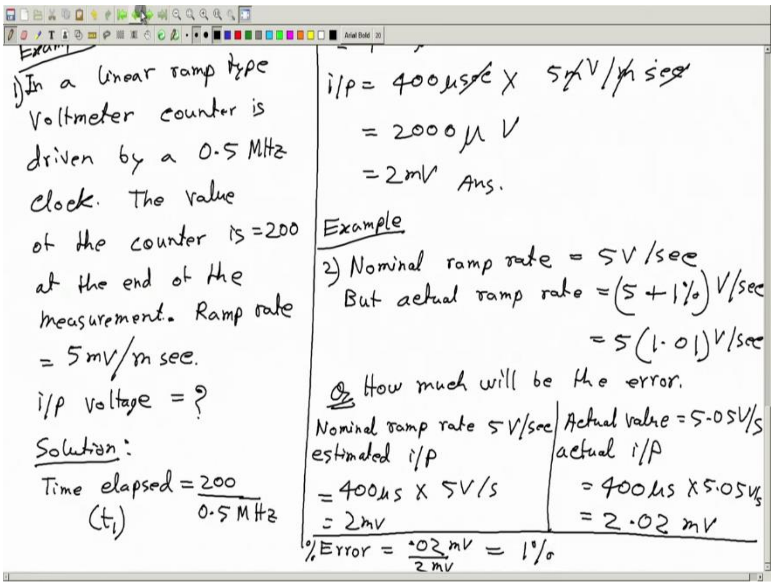

So, then how much is the error? Then error is nothing,

Error = $\frac{0.02}{2}$ = 1%

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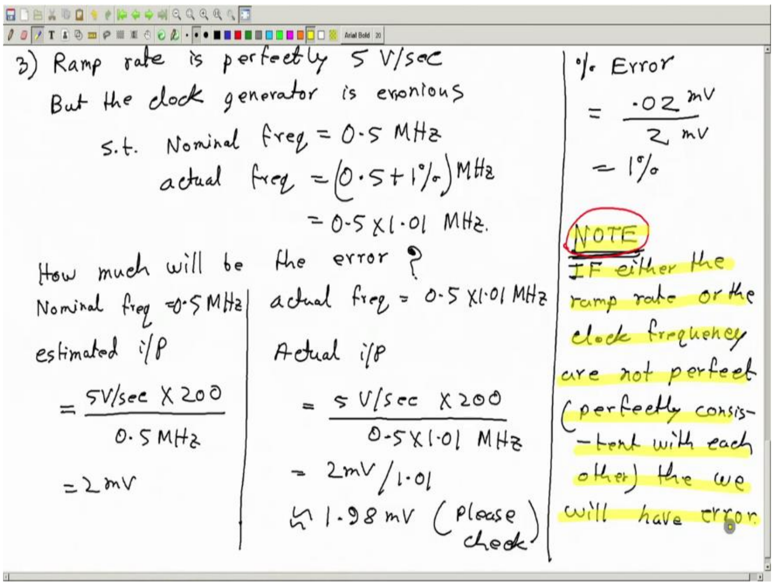


Now, let us take part 3 now part 3 ok. Now, assume that the ramp rate is perfect and it is perfectly 5 volt per second in the previous example ok. So, a ramp rate is exactly what is written in the specification no error at all, but the clock generator or the crystal is slightly erroneous is erroneous ok. Such that the nominal frequency how much it was nominal frequency 0.5 mega Hertz 0.5 mega Hertz, but actual frequency so, this is let me take this is 0.5+1% mega Hertz, this is 0.5x 1.01 mega Hertz ok. So, if this is the case then how much will be the error?

So, let us compare. So, nominal frequency is 0.5 mega Hertz and actual is 0.5 into 1.01 mega Hertz ok. Now, estimated input, how much is the estimated input? So

Estimated i/p = $\frac{5\ v/\sec x\ 200}{0.5\ MHz}$ =2 mV

Actual value = $\frac{5\ v/\sec x\ 200}{0.5\ x\ 1.01 MHz}$ = 1.98 mV

% error = 0.02/2 = 1 %

So, the error percentage error will be how much so, this is like so, the difference between these 2 is once again 0.02 or actually you can write a minus 0.02, if you want or let us forget about the sign divided by 2 millivolt by millivolt ok. So, this is once again 1 percent see, how I do.

Now, the essential point which I wanted to convey through these examples, this is also I mean exam pack or and this was also examples for our practice, but also there is a message, there is a message.

The message is that, if either the ramp rate or the clock frequency are not perfectly consistent with each other or not perfect for clock frequency are not perfect then I write perfectly consistent with each other, then we will have error in measurement ok. So, this is a problem with this is very important. So, I highlight it with many I also use the highlighters. So, this is really important ok. So, and that is why we will we shall see a other schemes, other modifications of schemes where this problem will be gone ok.

So, this is one point you must bear in your mind that, if either the frequency of the clock is deviating from the nominal frequency or if the ramp rate changes due to manufacturing or aging whatever, environmental factors then this meter will not give perfect result ok. Thank you, let us meet again with more sophisticated instruments, where this problem will not be there.

Thank you.