Electrical Measurement And Electronic Instruments

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Lecture – 64
Dual slope digital voltmeter- I

Hello. In our previous class we have studied linear ramp type voltmeters. What do we do there? Basically, we have a input, which is kept constant and there is a ramp voltage, which increases with time like this it goes up and up. And at some point it crosses the input. And, this time required for the ramp to cross the input tells us how large the input is. There we have seen a problem. The problem is that, if suddenly the ramp say starts to increase faster than it is supposed to be, then we will think the input is smaller than the actual value.

If, the ramp becomes say slower then we will think the input is more than it t sub actually ok. Similarly, the clock that we are using, the counter that we are using to measure this time, if the counter becomes faster, we will think more time has been elapsed. So, we will think the input is more, if the counter time might become slow, we will think the input is less than actual. To get rid of this problem we will see a new completely new, not completely new, slightly new modified version where this problem would not be there, ok. So, this is called a Dual Slope Voltmeter.

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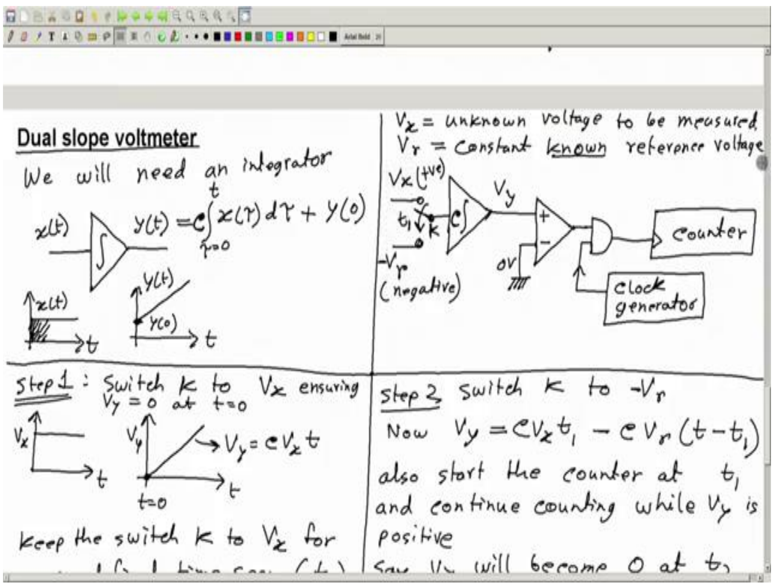

What do you have here? We have ok, for this we will need something new, we will need an integrator, ok. Integrated circuit we will talk about later separately, for now let us just understand what an integrator does, ok.

So, I integrator we will draw it like this, like op-amp triangle, this is because the integrators can be made with the op-amps, inside that we will put the integrators, integration sign, this is the input, this is the output. So, this is the symbol of an integrator, what it does; if I give the input as x t, then the output y t will be same as the integration of x t over time starting from say some time, some reference time t = 0 to sometime, call it; let me call this t, tau, tau, d tau, tau is the dummy variable, ok.

So, basically if say if input is like this let me take an example, if input is like this constant. So, this is x t, this is time, input is constant how will be the output? The output will be like this. So, if it starts from this value ok, it will then increase like this is y t ok. In general we can also have a integration I mean a constant, I mean the output can also be like this. This multiplied by some factor K, ok. So, input multiply input so, this is like a just the multiplication of something ok, it is possible that the output is K times x integrated over time, K can be 1 K can be not equal to 1 also, ok.

And, also I can put a starting value to be more precise, more mathematically precise, where y 0 is this y 0. This is what an integrator does? Basically, if you have a step input or a flat constant input. So, over time as time progresses you see the area under it. So, initially they this is area and then as time increases the area and that it increases as time increases more the area increases therefore, the output increases, that is what the integrator does, ok.

So, we will need this integrator, ok; then, what we will do? We will take the integrator, this is the input and we will have a switch here. So, this input can be connected either to this or to this, ok. Then, what I will do, ok. Now, these two inputs are one of them is unknown let me write V x, where V x is unknown voltage to be measured. And, this called it V r; V r is a constant known reference voltage. So, we have these two things.

And, now let me connect comparator here, ok. So, what does this comparator do? It compares whether this value is higher than 0 volt or not, ok. Now, from this we will drive a counter. So, this is the clock, we have to drive it through AND gate like we did previously.

So, from this clock generator signal comes here and it goes to this counter, ok. So, the counter will count when this value is logic high, this is a schematic only to you remember this is not a electrical circuit to be laid out exactly. So this, when this is high you think it in this way, when this is high, then this counter will count. Now, what we will do this is not yet complete, ok. This is not yet complete; I will complete this as I tell you this story also side by side. So, the way we will measure is that call this K, ok.

So, step 1 connect or switch K to V x ok; switch K to V x. So, what will happen? And, V x is a constant input, ok. So, if I connect this here, then this output will start increasing, ok. So, what will happen? If, this is a say V x, which is constant then t versus call this y, V y; then, V y will increase like this, ok. It will increase like this and assuming that it, not assuming it is necessary that, it starts from 0, ok.

So, when you connect this switch K to V x make sure that the comparator sorry integrator output is 0, ok. Ensuring V y = 0 at this moment, at t = 0 all this is t = 0, ok.

So, what do we do we first somehow ensure that the output of the integrator is 0 ok; so, this is 0, then we connect the input to V x. Therefore, the output will now start to grow from our value of 0 to some value. How fast will this grow? This will depend on the value of V x, ok. And if we if the integration constant is I have already used K here, ok.

So, there is a conflict of so, let me call this constant as C ok, C is the multiplication factor which gets multiplied with the input. So, if this has this factor C ok. Then, this I can write this as a function of time I can write this is same as

V y = C V x t

This is V y how it is increasing? It is increasing with time linearly, ok. Now, keep the switch K to V x; that means, here for a predefined time predefined time span call it t 1 ok. So, let this output increase only for time t 1, after that we are going to stop it, ok.

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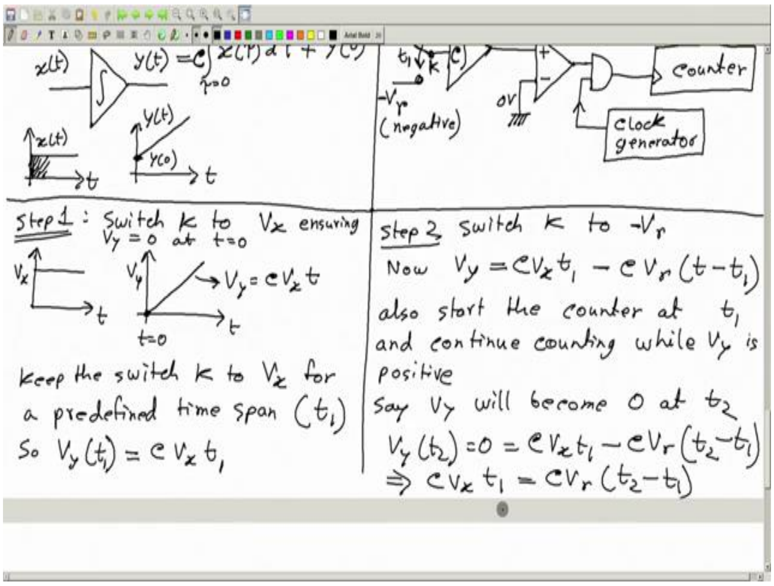

So, V y at time t 1 will become how much this is we just let put this t 1 C V x t 1. So, this is how much this output will grow in time t 1 right; fine ok. Now, after that what to do step 2 ok, let me do it here switch K this K to V r, which is a constant reference voltage, ok. And, let this V r be negative, ok. So, call it minus V r ok. So, this is a negative value like minus 5 volt V r is 5 this is – 5, - 1 volt something. So, they will switch to this, ok. Now, this is connected to this when at time t 1 ok. So, at t 1 bring this switch here, ok. Now, what will happen? Now, this output will so now, this V y will be how much.

It will now start to decrease ok, because now input is negative and if you integrate a negative value, then the result decreases with time, right. So, now, the output will start to decrease, when it was here so, assuming this so, this was positive. So, it was in so, the output was increasing now output will decrease ok, that is important previously it was increasing now it is decreasing.

$V_y = c V_x t_1 - c V_r (t - t_1)$

And one more thing, ok; so, at this moment we are switching it and we will also start this counter at t = t 1 ok. So, let me write. So, also start the counter at t = t 1 or at t 1 simply and continue counting, while V y is positive. So, V y was positive initially at t 1 and then it is decreasing and so, if it is decreasing at some moment it will come to 0. So, when will it come to 0 so, say V y will become 0 at t 2, ok.

Vy t2 = 0 = cVx t1 – cVr (t2-t1)

cVx t1= cVr (t2-t1)

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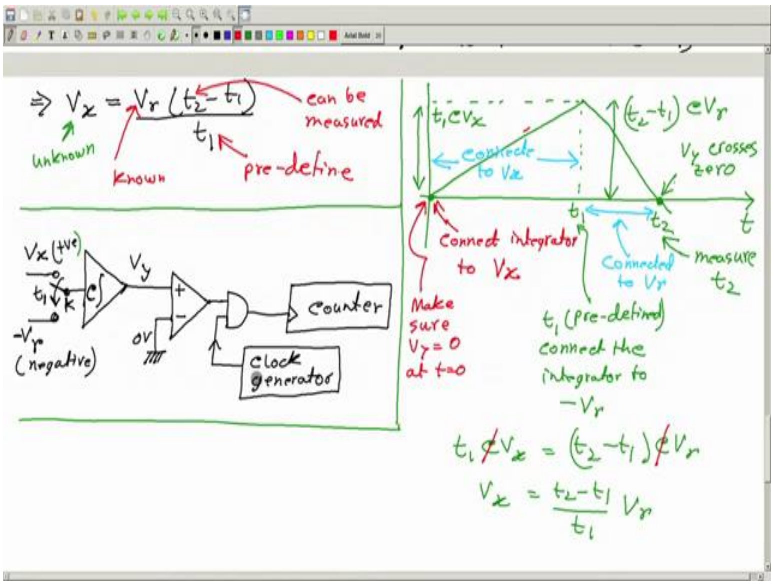

Vx = $\frac{Vr\ (t2-t1)}{t1}$

this time is a predefined time fixed time, t 2 can be measured how using the counter. So, that is why we say it start the counter at time at this moment, ok. So, this counter can help me in measuring this time ok. So, this can be measured. So, therefore, so, all these quantities on the right side, this is known, this is known, this is known so, this unknown can be found from this right. So, this is the essential scheme in this measurement, ok.

Let me also tell you to make it maybe possibly clearer, let me explain this also again with some timing diagram, ok. Let me keep it here for easy reference, ok. Now, let us see how V y changes, ok. So, this is say time and V y will start from 0. So, I write this makes your V y = 0 at time = 0, then at this moment we will connect the integrator to V x.

So, at this moment we will also connect the integrator at this moment, ok. Therefore, V y will start to grow. So, V y will start to grow from this like this ok. And, at what rate will it grow, it will depend on the value of V x; higher the value of V x it will grow faster ok. Smaller the value of V x it will grow slower, ok. And, then let this be time t 1 ok, now for t 1, I this is a pre-defined time, pre-defined pre specified time, here connect the integrator to minus V r reference voltage, ok.

So, now this is a negative value, now the input is negative. So, output will start to decrease so, the output will now start to decrease like this. And, at some moment here so, this is the moment when the V y crosses 0, ok. So, this comparator is put here to see, when V y crosses 0, the purpose of the comparator is this, ok. The moment V y crosses 0 something will change at the output which will tell ok, this is the point when V y is becoming negative call this time t 2; t 2 is to be measured. Measured this, measure this value, measured t 2; t 2 is to be measured ok so, basically we have to measure this time right.

Now, from this what can we say, so, how much is this height, what can you say about this height; we can say this height is same as this slope multiplied by this time. So, this we can write t 1 time multiplied by the slope. And, the slope is equal to slope will be equal to proportional to V x and this constant C, C V x more the V x this will be higher, less the V x this will be smaller. And, C is a constant of this integrator which is a property of this integrator so, this is this height.

And, if so, now from this side, considering this side, what can we say about this height we can say this is this time multiplied by this slope, right. So, how much is this height is therefore, the same height, I can write now this time is t2 - t1 multiplied by this slope, how much is this slope? So, in this period this is connected to V r. So, the slope is C V r right. So, from this side I can calculate this height to be C V r times this minus I am I can ignore because I am talking about the height the absolute value ok. And, from this height I have computed this height to be this. So, from this I can write t 1 C V x is same as (t2-t 1) C V r, because this is the same height. And, from which you can calculate the value of V x, right.

So, this is the period when the integrator is connected to the V x. So, connected to V x here. And, this is the period where it is connected to V r, ok. From this time measured, you can measure this unknown voltage right. Now, and the important question here is ok, now this is the important question. Important question is that we have to discuss is this method since it gives to change in clock, this clock frequency or some changing this integrator property, ok.

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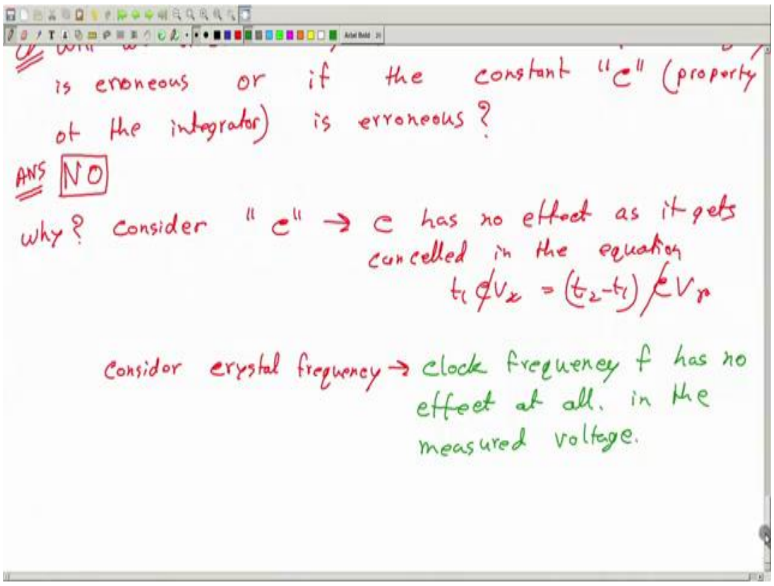

So, this is the important question will we encounter any error if the crystal frequency say, or clock frequency is erroneous is changing with time slightly, or if the constant "C" ok. This is the property of the integrator ok. So, this constant, this constant or in this equation, this constant if this is changing or if this constant C is erroneous?

Then, will it lead to any measurement error any error in the measured frequency, this is the question and the answer is no. Why? So, let us consider first this constant C ok, consider "C". What happens if the value of C is increased means the integrator is changed due to some problem due to edging or something so, that the for the same input now the output will increase faster, ok. If, that happens is that a problem no, because what will happen is that both this part will increase faster as well as this part will decrease faster.

So, their effect will finally, get cancelled nullified, you can also see this in this equation where we see that this constant C is in the both side and therefore, they get cancelled. So, even the value of C is changed if C is changed by 1 percent 2 percent even more, this is changed in both side, this cancels from both side, ok. So, therefore, C has no effect.

So, C has actually no effect at all; C has no effect as it gets cancelled in the equation what was the equation, t 1 C V x =(t 2 - t 1) C V r sorry, ok. So, this has no effect. Now, consider crystal frequency, ok. What is the role of the frequency of this clock generator? Ok; so, we have we do not have this frequency in any of these expressions. So, does it have any role at all in the measurement? Yes it has how, because we actually do not measure this time t 1 or t 2. We actually measure the number of I mean we measure the number of clock pulses in these two periods here and here or remains we watch the we see the counter value in this period and in this period. ok.

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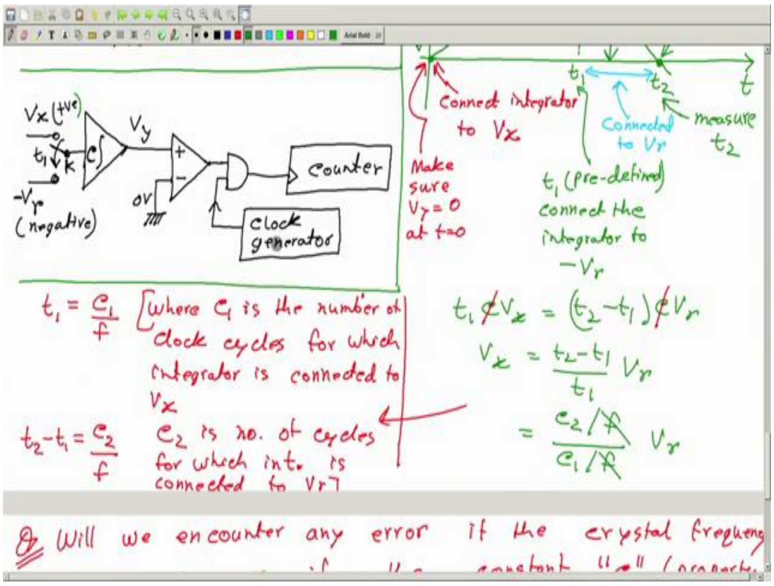

So, actually we do not have the value of t 1 or t 2. What we have is this; I mean, we actually have t 1 = C1/ f where, C 1 is the counter value at this point, ok. Say, say if the counter starts here ok, then it will be the value of the counter here or I may also start the counter here I may not so, I withdraw my last statement that may be confusing.

So, let me rather write where C 1 is the number of clock cycles for which integrator is connected to for which the integrator is connected to V x. So, for how many clock cycles this switch is connected to V x that is C 1. And, similarly t 2 - t 1 this will be same as call it C2/ f, where C 2 is the is number of cycles for which integrator is connected to V r reference value, ok. And, f is the frequency of this j clock generator, ok.

So, basically here therefore, you can actually write this is what; this is C2/f and this is what C1/ f V r, ok. Once, again you see this f and f cancels; so, therefore, the frequency of the clock generator will have no effect, ok. So, the frequency of the clock generator has no effect. Even, if it changes slightly absolutely no problem it can change only thing ok, what will change?

So, if the frequency is changed say this if this clock frequency changes, it will change the time required for measurement, ok. We will discuss it more later in the next class ok, but it will have no effect in the measured value, I should write no effect at all in the measured voltage, it can have other effect, ok.

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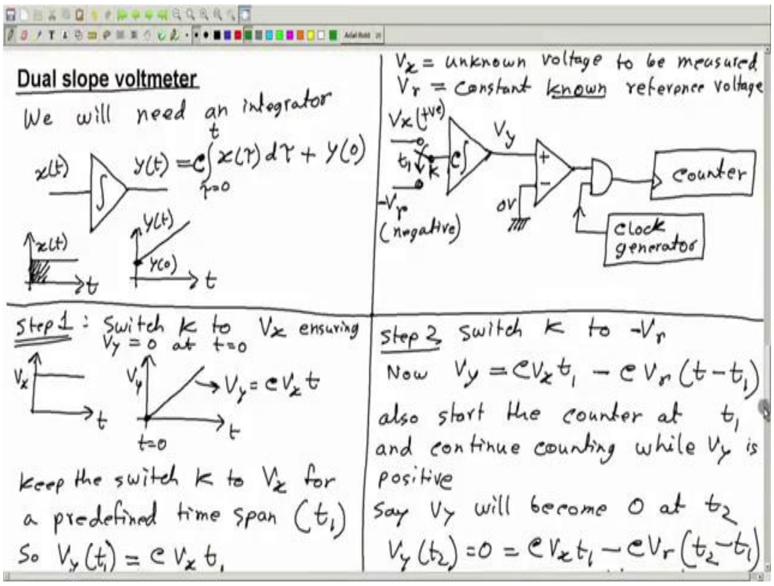

So, I request that you just think about this scheme update we will come back and we will talk about it more we will take numerical examples. So, that the idea become more and more clear.

Thank you.