Fundamentals of Power Electronics
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Lecture - 84
Base drive with speed-up circuit

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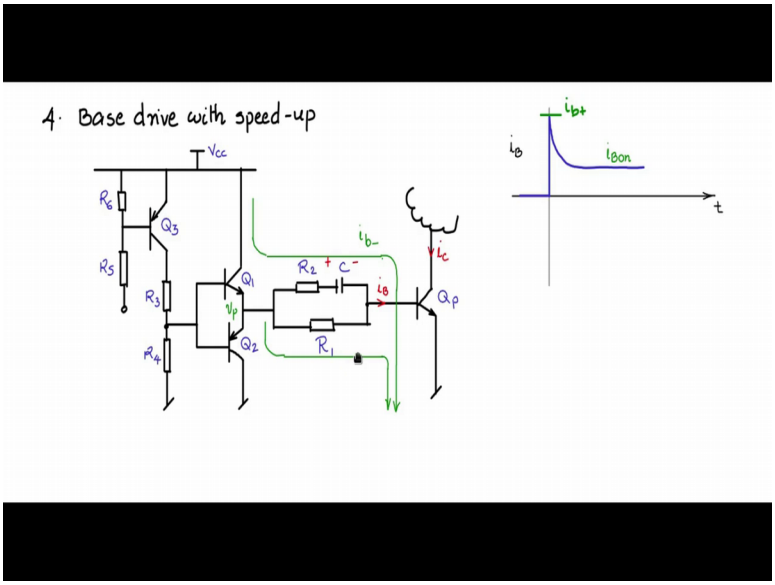

Let me now discuss another interesting Base drive circuit with speed-up; speed-up of both turn on and turnoff. Let me start with a PNP transistor, the PNP transistor the collector is connected to a resistance 2 resistance divider like this. And from the centre point of the resistance division I will pick of a point, pick of a line and then connected to the base of an NPN transistor like this.

The emit of the NPN transistor on the collector of a PNP transistor are connected in this fashion, collector is grounded and the same base is given to this PNP transistor also and the collector of the NPN is connected to the V cc. So, you will see that across this V cc you have an NPN, PNP transistor combination connected in this fashion is called the Totem pole combination.

Now, when the NPN transistor is on because the base is more positive with respect to the emitter the base of the PNP is also connected to the same point. So, the base of the PNP is also more positive with respect to the emitter therefore, the PNP transistor is off. So, when the NPN transistor is off and the PNP transistor is on the emitter is more positive as

compared to the base and the PNP transistor is on and because the emitter is more positive than the base NPN transistor is off. So, the on and off of this NPN and PNP complements are always mutually exclusive. So, there will never be a direct short from V cc to ground ok.

Going further let me mark that a V cc and the base drive for this PNP we have already discussed, it is 2 resistance combination and at this point here you can give V b, the base drive from a base drive source. Now, from this centre point of this totem pole I will pass it through one network R and C combination like this in series. And another in parallel resistor like this and connected to the base of the final transistor or the power transistor.

Final power transistor is connected on external load and i c of that is what is supposed to be switched on and off that we need to control, this is Q p. Now let this; let me call this as R 1 this is R 2, C this is Q 1 this is Q 2 this is Q 3 R 3 R 4 R 5 R 6 V cc. This portion of the circuit R 1 R 2 C now this is the portion of the circuit that we will be calling as the speed up circuit or the speed up network.

So, in this speed up network this branch R 2 C branch is the first dynamic branch R 2 C time constant is having a time constant of the order of turn on times or the turn off times of the Q p BJT. So, during transition, during turn on and turnoff R 2 C branch is very active and during the steady on time R 1 is the active branch.

So, let us see how this operates. Consider now this point here is the pole voltage V p. Now, consider the state when Q 1 is off. So, and then Q 1 is off there is no current flowing through in this direction Q p is off. So, Q p is you know off state.

Now, at this stage let us switch on Q 1; how do we switch on Q 1? Q 3 is switched on. How do you switch on Q 3? Make this low, so when you make this low there is a possibility for current flow like this. So, you have i B ON flowing like this i B ON flowing like this then you have Q 3 on. When Q 3 is on there is a drive current flowing through R 3 into this branch here and it is flowing in this direction Q 1 is on; Q 1 is on Q 2 has to be off. So, when Q 1 is on there is a drive current that can flow through into the speed up network.

So, how does the drive current flow let us say a drive current flows like this and through this R 2 C network in this fashion because initially when the Q 1 is turned on the

capacitor C acts like a short R 2 is much smaller compared to R 1 major portion of the current flows through like that in this fashion through the R 2 C branch.

There is also a parallel division current flows through R 1 branch also, but the current through R 1 branch is lesser than the current that is flowing through R 2 branch. Then as time progresses this exponentially decays; exponentially decay in the R 2 C branch because C gets charged up plus minus and when C gets charged up plus minus 2 V cc the current through this branch C this and it is only the current through this branch that flows and this should be the steady on state current.

So, let us say plus minus the C charges in this fashion and let us draw the time wave form and see how it looks. Let us say this is i B current; i B current flowing in through 2 Q p how does this waveform look like, will plot i B. So, i B was 0 during the time Q 1 off and Q 1 was turned on there is a surge here. So, that surge is i B ON which is flowing through R 1 plus there is as surge due to R 2 C branch. So, let us call that one as i b plus.

So, from i b plus there is a steady decrease because C is getting charged plus and minus and gradually this branch will not conduct current and only this branch will conduct current. So, whatever the steady on current is flowing through R 1 will be i B on and then again during switch off turn off, now Q 1 is turned off you make this high Vb is made high here. Q 3 will turn off and Q 1 will turn off and because of that Q 2 here will now turn on because C here is having positive charge, this is positive and the base of Q 2 the PNP is now connected through R 4 to ground which is at the lower potential.

So, there is a possibility of current flow through like this and current flow through like this. So, you will see that Q 2 will turn on and there will be a current flow through Q 2. So, we will call this i b plus and this is i B on and then during the time and Q 1 is being switched off.

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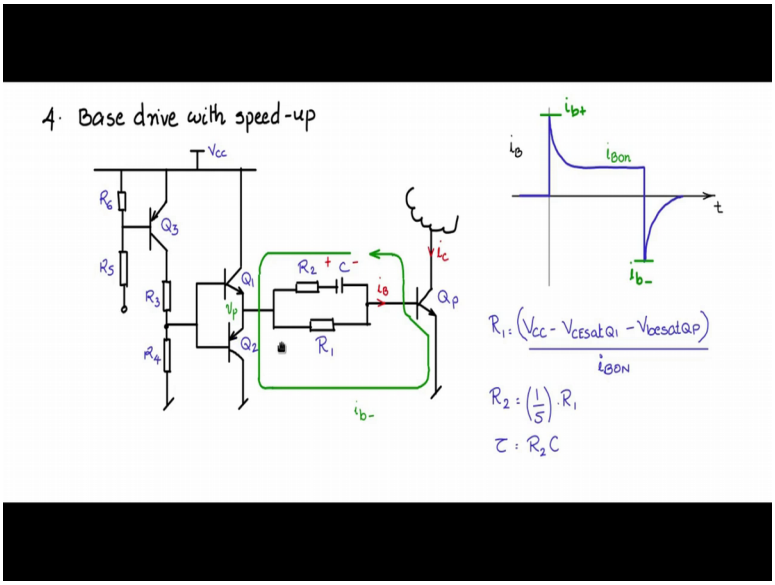

We will see that charts current starts flowing in this fashion down through like this surge flowing like this and through in this direction. So, that the base charges start recombining and comes back and completes the circuit here. So, this is the negative current. So, this is the negative current that we are seeing that needs to flow through Q p. So, that Q p turns off as fast as possible and there is base charge recombination.

So, this point here we will call that an as i b minus. So, this current which will flow through starts with i b minus and gradually exponentially decay the charge on this capacitor starts decreasing. So, as the capacitor charge start decreasing the current here starts decreasing in an exponential manner. So, the current will decrease in an exponential manner to 0.

So, once this decreases to 0 all the base charge has been recombined and Q p has regained its off state. So, here we know how to design R 3 R 4 R 5 R 6 the two resistance drive, the new part is this network. So, let us calculate R 1; R 1 is supposed to handle steady i B on current. So, let us say during the steady i B on portion the potential on this side of the R 1 V p is V cc minus V CE sat Q 1 that is this point. So, we will write that down V cc minus V c sat Q 1 and on that side you are having V be sat Q p V be sat Q p the whole divided by i B on current this will give you the value of R 1 R 2 needs to be much smaller than R 1. So, you use a constraint let it be one-fifth of R 1.

Then order to calculate C we know the time we should start with the time constant R 2 C

tau R 2 tau which is the time constant is R 2 C, now how do we choose that tau. Now this is the term on time, this is the term off time. So, the turn off time let us say is comprising of storage time plus fault time turn on time is comprising our i c time, look into the datasheet of the Q p BJT and choose tau comparable to the turn on or turn off times of the BJT. So, let us say you have t s storage time and you have t f fault time t s plus t off tf t fall can be fixed as the time constant R 2 is known and C you can calculate. So, C can be calculated in this manner.

So, by making tau the time constant smaller and smaller the speed up can be made much faster. So, this is the base drive which has both turn on speed up and turn off speed up and it is an interesting base drive circuit and this effects only that portion of that network base drive network just immediately before the main power transistor. Then following that you have this totem pole following that all the sections and if you have still more further multistage sections all will be just like as we discussed before 2 resistor NPN PNP combinations. You have a 2 resistor NPN drive and 2 resistor PNP drive alternately coming into the picture to form a multistage drive with speed up.