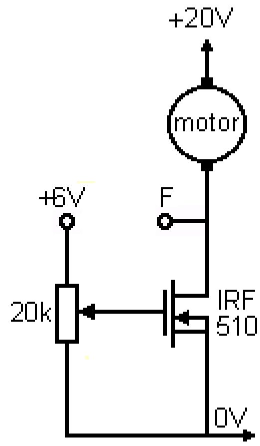
Nipkow disc motor control

It is not so easy to explain how the motor control for an NBTV Nipkow disc works. But let me try.

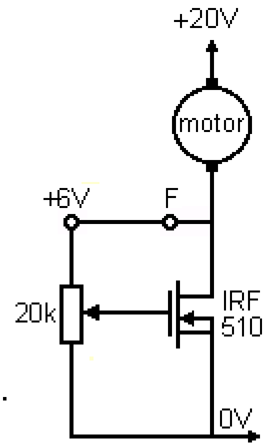
1. The motors we use are so called Permanent Magnet (PM) motors. This motor has a speed proportional to the applied voltage. So at a certain voltage it runs at a certain speed. At a lower voltage it runs slower, at a higher voltage it runs faster.
2. The more work the motor has to do, e.g. rotating a large Nipkow Disc, the more current the motor will draw, but at the same voltage it will run still at (almost) the same speed.
3. The motor is controlled in speed by a Field Effect Transistor, e.g. an IRF 510. See the circuit right. With the potentiometer of 10k we can change the voltage at the gate of the FET.
4. If the voltage on the gate is lower than about 3 volts, the FET is not conducting. So the motor is stalled. The voltage over the motor is zero. The voltage at point F is +20V higher than "ground" (0V).
5. If we make the gate voltage higher than 3 volt the FET starts conducting. The motor starts running. The voltage over the motor goes up and the voltage on F goes down.
6. If the voltage at the gate is e.g. 4 volt the motor is running fast. F might have dropped to 0 volt, so there is 20 volt over the motor.
7. Somewhere between 3 volt and 4 volt the motor is running the correct speed, such that the disc runs 12.5 rev. per sec.



8. Suppose that with this motor and this Nipkow disc the motor runs 12.5 rps with a voltage of 14 volts over the motor. Then the voltage at F is 20 – 14 is 6 volts.

Voltage feed back

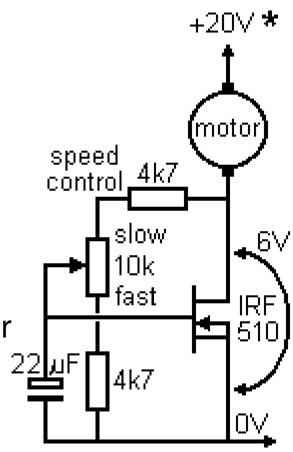
9. It is very difficult to get the motor speed at 12.5 rps, as every disturbance slows down the motor speed. This will also drive the voltage on F up or down.
10. We need some means to stabilize the 6 volts at F. We can do so by getting the +6V not from a stabilized power supply, but from F.
11. Look what happens: If the motor slows down, the voltage at F goes up, the voltage at the gate goes up and the FET starts conducting more.
12. Then the motor get running faster, which drops the voltage at F and so on. This keeps the voltage at F very stable at 6 volts.



13. Small changes in speed can be corrected by adjustments of the potentiometer (20k). The voltage at the gate will be kept almost at the same value (3.5 volt). To obtain that the voltage at F must be somewhat higher (slower motor) or somewhat lower (faster motor). So the potentiometer can be used for some speed control.

Motor interference

14. A rotating PM motor gives back a voltage, as if it was a running dynamo (generator). This is not a clean DC voltage, there are quite some peaks and dips, due to the mechanical commutation. These should not be fed back to the gate of the FET. An electrolytic capacitor, 22µF smoothes the peaks and dips.
15. Because we need only the centre part of the speed control potentiometer we can split it up in 10 k potentiometer and 5k at both sides.

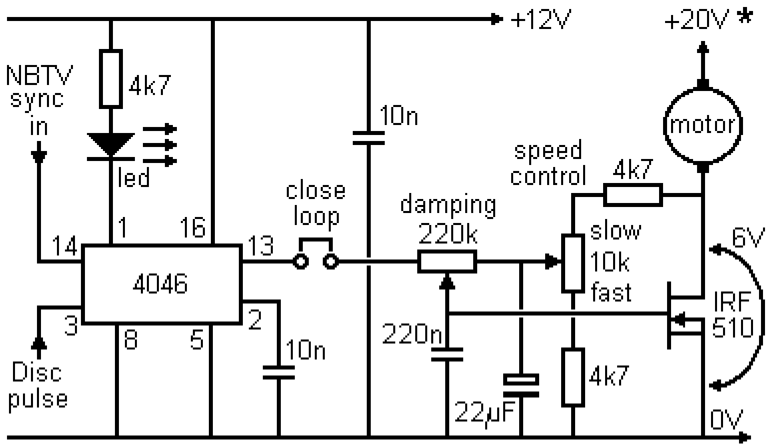


Other motor

16. It is important that the voltage at F should be about 6 volt. So if we have a different motor, one that runs, with disc, at 12.5 rps at a voltage of say 8 volt, we need a different supply voltage at the top of the motor. For the 8 volt motor: 6 + 8 = 14 volt.
17. The voltage of the motor is between point F and the motor supply voltage. Point F is kept constant by the voltage feed back. But if the supply voltage varies, e.g. because it is an unstabilized unregulated supply voltage, the motor speed will change at all changes of the voltage of the mains (power grid). At the end this will be compensated by the positionl feed back, but that will be visible in the position of your NBTV picture. So it is a better idea to have a stabilized supply voltage for the motor.
18. It is not needed that this supply voltage is exactly the calculated optimal value. My guess is that the voltage at F should be between 5 and 8 volt, so a margin of 3 volt.
19. Then first check the circuit until here, adjust the speed of the Nipkow disc to 12.5 rps and measure the voltage at point F.

Position feed back

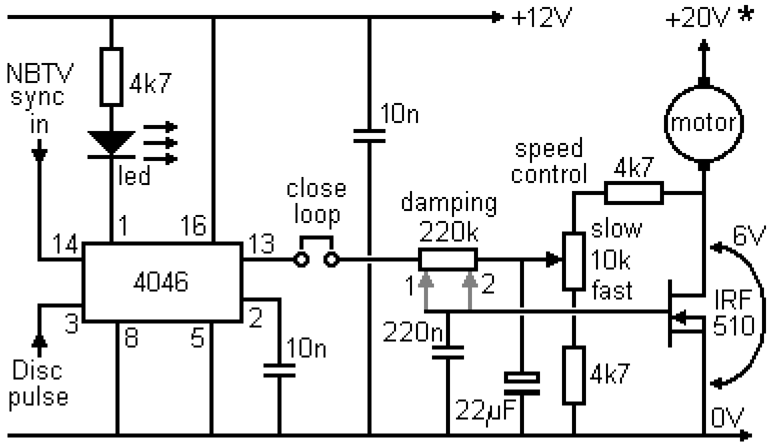
20. The 4046 compares the arrival of pulses from the optical disc sensor and pulses from the NBTV sync. If they arrive at the same moment the output, pin 13, is doing nothing, it is floating.
21. If the disc pulse comes a little bit earlier, the 4046 output connects to ground (0V) until the sync pulse comes. This is a pulse with the duration of the arrival difference. This will discharge the capacitor 220n a little bit. The motor will slow down somewhat.



22. If the sync pulse comes first, the output connects to +12V until the disc pulse comes. This will charge the capacitor a little bit and the motor will speed up somewhat.

Stability

23. These actions should not go too fast, but also not work too slow.
24. If they work too intense, the motor speed changes too much and the next pulse pair differs even more in arrival time. The system becomes unstable.
25. If they work not intense enough, the reaction of the disc is very little and it takes too much time before the NBTV picture is in the correct position.
26. Here the "damping" control comes into operation.
27. If the potentiometer is in position 1 (left) the influence of the 4046 is large. An unstable system.
28. In position 2 the influence is low. A stable but slow position control.
29. Somewhere in the middle is the optimal position. The question is: "How to find this?".



Critically damped

30. Follow this strategy:
    a. Open the loop by opening the jumper connection,
       or place the damping control completely in position 2.
    b. Adjust the speed control for an almost stationary NBTV frame in your viewing window.
    c. Close the loop jumper, if you have it.
    d. Adjust the damping potentiometer somewhat to the centre position,
    e. you will see that the NBTV frame will come to a stand still.
    f. Touch the rotating disc shortly with your finger;
    g. the standing frame will move and will slowly come back to its previous position.
    h. Put the potentiometer somewhat more to the centre position and repeat f and g,
    i. the recovery will be faster.
    j. In small steps make it faster and faster,
    k. until you see that there is coming some overshoot in the recovery.
    l. If you continue, you will see that after the overshoot there are more overshoots
       and it takes quite some time before the picture comes to a stand still.
    m. If you go too far, the picture will never come to a halt, but keeps hunting.
    n. The optimal setting is at k, one overshoot, no more.
    o. this is called critically damped.

Manual frame sync

31. You may use the "close loop" jumper for manual frame sync. Then
    - open the loop and adjust the speed control or just wait for the frame-synced picture.
    - Then close the loop.