Some thoughts on a simple two transistors blinker.

This is an astable relaxation oscillator that has two states: one when the lamp is off and one when the lamp is on. The output is a square wave.

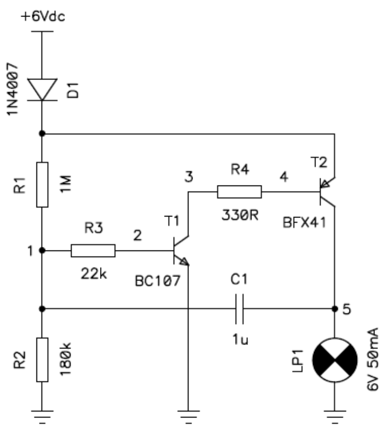

Figure 1: Oscillator schematic diagram.

When the lamp is off, capacitor C1 charges via the voltage divider R1-R2 and the lamp LP1. The lamp has a resistance of about 120Ω, much lower than the equivalent resistance R1//R2 (152kΩ) and can be neglected in calculating time constants. In addition, the current charging the C1 (about 5µA) is too low to make the lamp burn (nominal 50mA). Of course, removing the lamp will stop the oscillator.

As soon as the voltage on T1's base reaches its conduction threshold (let say 0.6V, at node 1), this NPN transistor starts conducting pulling current from T2's base through R4. T2, which is a PNP, will start conducting as well. A current will start flowing through the lamp LP1 and the voltage at node 5 will rise. This voltage rise is reflected back via C1 on T1's base making it conducting even more and further rising the voltage. This positive feedback makes both T1 and T2 saturate very rapidly: the voltage rise on the lamp is very sharp.

When the lamp is on the voltage across it (node 5) is almost the supply voltage (5.3V) since T2 is in saturation. C1 is still charged (switching time is much shorter than RC time constants of C1) and the beginning of this phase voltage on node 1 is above the supply rail. This makes C1 discharge through R3, the base-emitter junction of T1 and the lamp.

While C1 discharges voltage on T1 gradually quits saturation and its collector current gets weaker. This can be seen by observing T1's collector voltage (node 3) that quits zero and start to rise. Since T1's collector current is T2's base current, T2 will also quits saturation shortly after T1; as soon as this happen the voltage on the lamp starts dropping and because of the positive feedback through C1 the voltage on T1's base will drop and the lamp will be switched off very rapidly with a sharp falling edge.

The voltage on T1's base is critical. If it is too low, the oscillator will not start; if it is too high, the lamp will switch on and stay on forever. For this reason, the voltage divider R1-R2 reduces the voltage and ensures stable oscillations.

The gain of T1 is critical as well and should not be too high; otherwise the lamp will stay on forever. For this reason, in some circuits T1 is mounted in reverse mode (with emitter and collector swapped). Resistor R4 helps reducing the effect of T1's gain by limiting its collector current.

Time constants can be easily be calculated: when charging (lamp off) it’s determined by R1 and R2 in parallel multiplied by C1. τ_{off} = 152ms. When discharging (lamp on) it’s simply R3 multiplied by C1. τ_{on} = 22ms.

Unfortunately the reality is a bit different: the measured charging time constant τ_{off} is 250ms (65% higher), assuming a true 1µF capacitor, this corresponds to an equivalent charging resistance of 250kΩ). The measured discharge time constant τ_{on} is 39ms (77% higher), corresponding to an equivalent discharge resistance of 39kΩ.

Measured on time is 160ms, period is 900ms, meaning a frequency of 1.1Hz and a duty cycle of 18%.

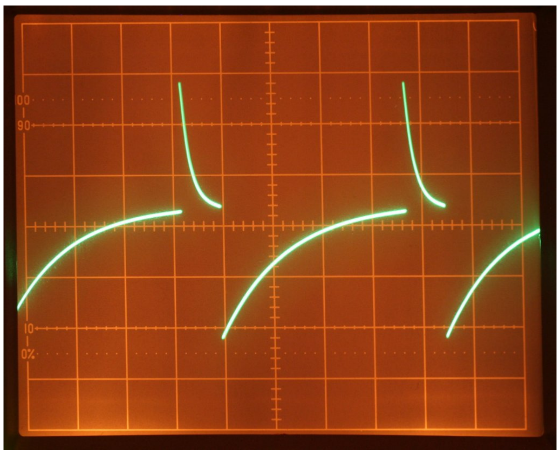

Figure 2: Voltage on R1-R2 divider (node 1), vertical 2V/div, horizontal 200µs/div.

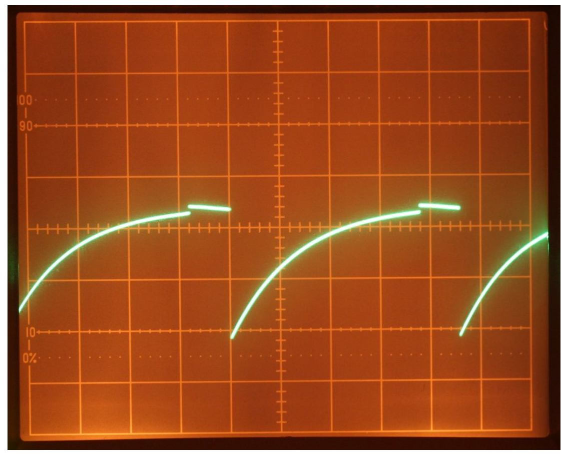

Figure 3: Voltage on T1's base (node 2), vertical 2V/div, horizontal 200µs/div.

Figure 2 shows the voltage on node 1. As one can see the voltage has nice exponential shapes, but charge and discharge traces are shifted by the voltage on the output (figure 6) making a spiky plot.

Figure 3 shows the voltage on T1’s base. This is almost the same plot as in figure 2 but positive peaks are clamped at about 0.6V by T1’s base-emitter junction.

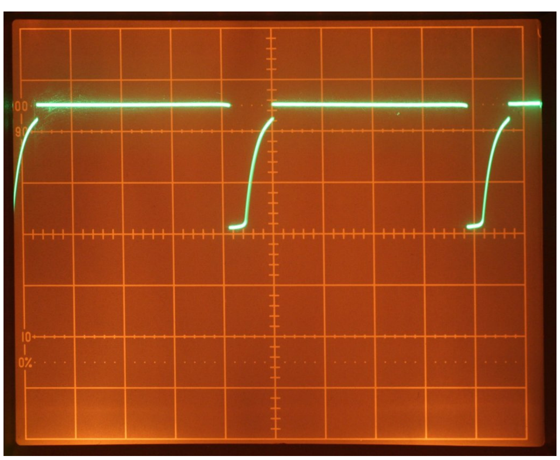

Figure 4: Voltage on T1's collector (node 3), vertical 2V/div, horizontal 200µs/div.

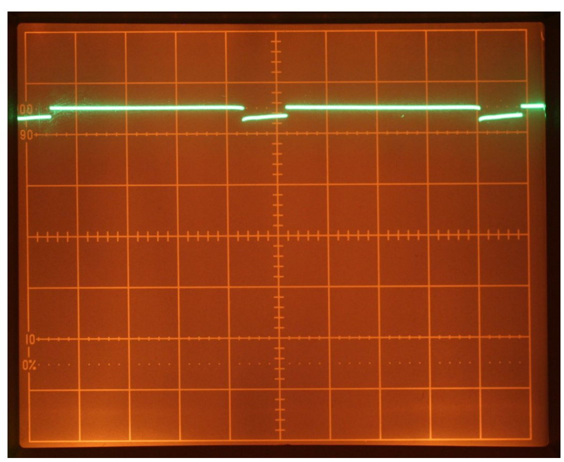

Figure 5: Voltage on T2's base (node 4), vertical 2V/div, horizontal 200µs/div.

Figure 4 shows the voltage on T1's collector. When T1 is saturated, the voltage is close to zero, then when it gently quits saturation the voltage rises almost reaching the positive rail before T2 also quits saturation making the output quickly drop.

Figure 5 shows the voltage on T2's base. Here the saturation of T1 is not visible since the voltage is almost the positive rail when T2 is off and just drops by 0.6V when T2 saturates.

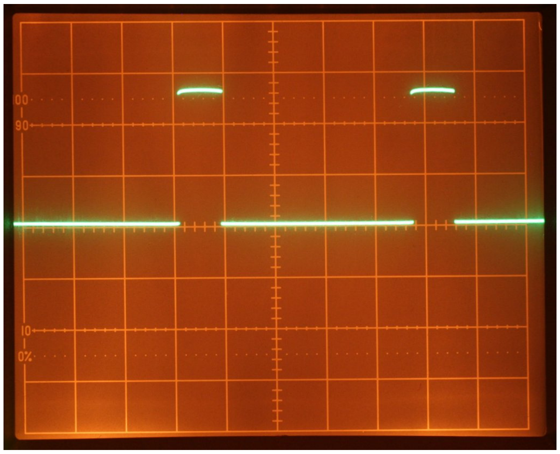

Figure 6: Voltage on the lamp (node 5), vertical 2V/div, horizontal 200µs/div.

Figure 6 shows the voltage on the lamp (node 5). As one can see the output voltage is a nice square wave with sharp edges.

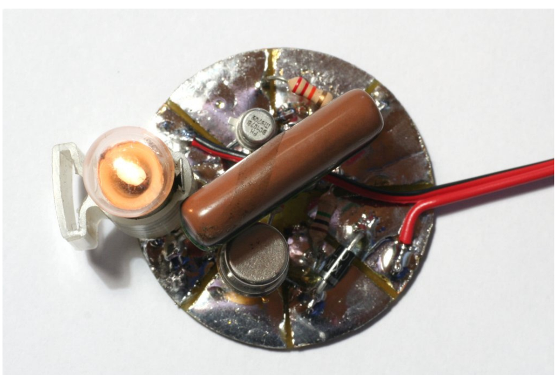

Figure 7: Oscillator top view.

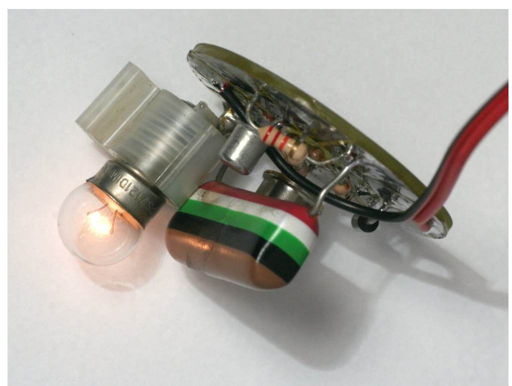

Figure 8: Oscillator side view.

Figure 7 and figure 8 show the prototype used for the measures shown above, assembled with vintage parts and assembled in an old-fashioned way.