SWARM South Western (Ontario) Association of Rocket Modellers

Transolve MF-20

Launch Control System

Introduction

The Transolve Multi-Fire 20 (MF-20) is a versatile electronic based launch control system capable of firing up to 20 launch pads, either individually or in groups. The system makes use of low current control and continuity checking techniques and can operate over several hundred feet, ensuring that the NAR safety distances for launch events are met.

Circuit Overview

Reference is made to the overview schematic provided in Figure 1.

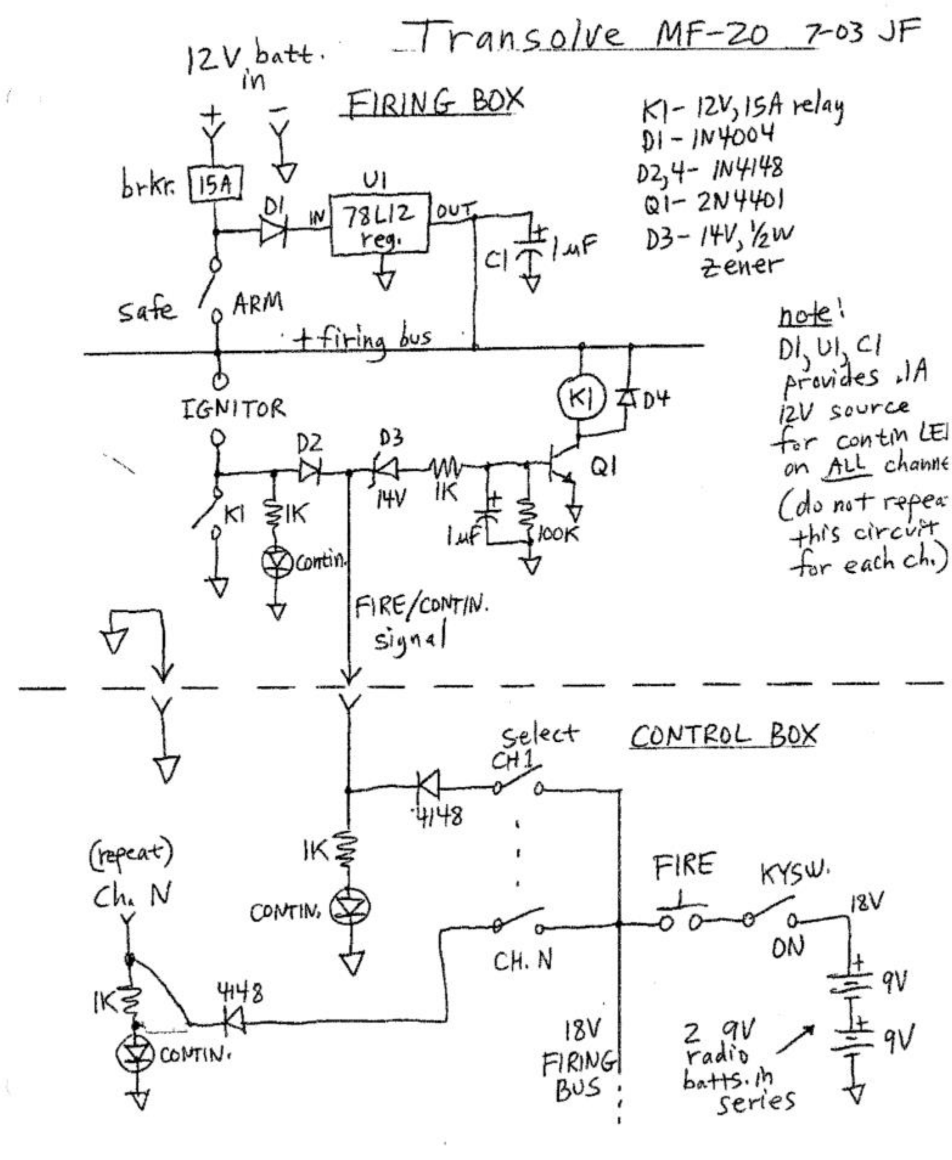

Figure 1: MF-20 Overview Schematic

Note that the schematic shown in Figure 1 illustrates the continuity and firing control for one pad; this circuit is replicated for each pad controller. Only the batteries, the LCO Console Launch pushbutton and Safety Key Switch, and the Firing Box Circuit Breaker and continuity check current limiter are common elements to all of the pad circuits.

System Disarmed – Key Switch removed from the LCO Console

In this state, it is not possible for the system to fire an igniter. Control power to the launch circuit is removed.

Provided that igniters have been connected correctly, a valid continuity indication will be provided both locally at the Firing Box and at the LCO Console. This will be true for all igniters present and connected in the system.

Figure 2 illustrates the continuity check current path when the Firing Box is in SAFE mode:

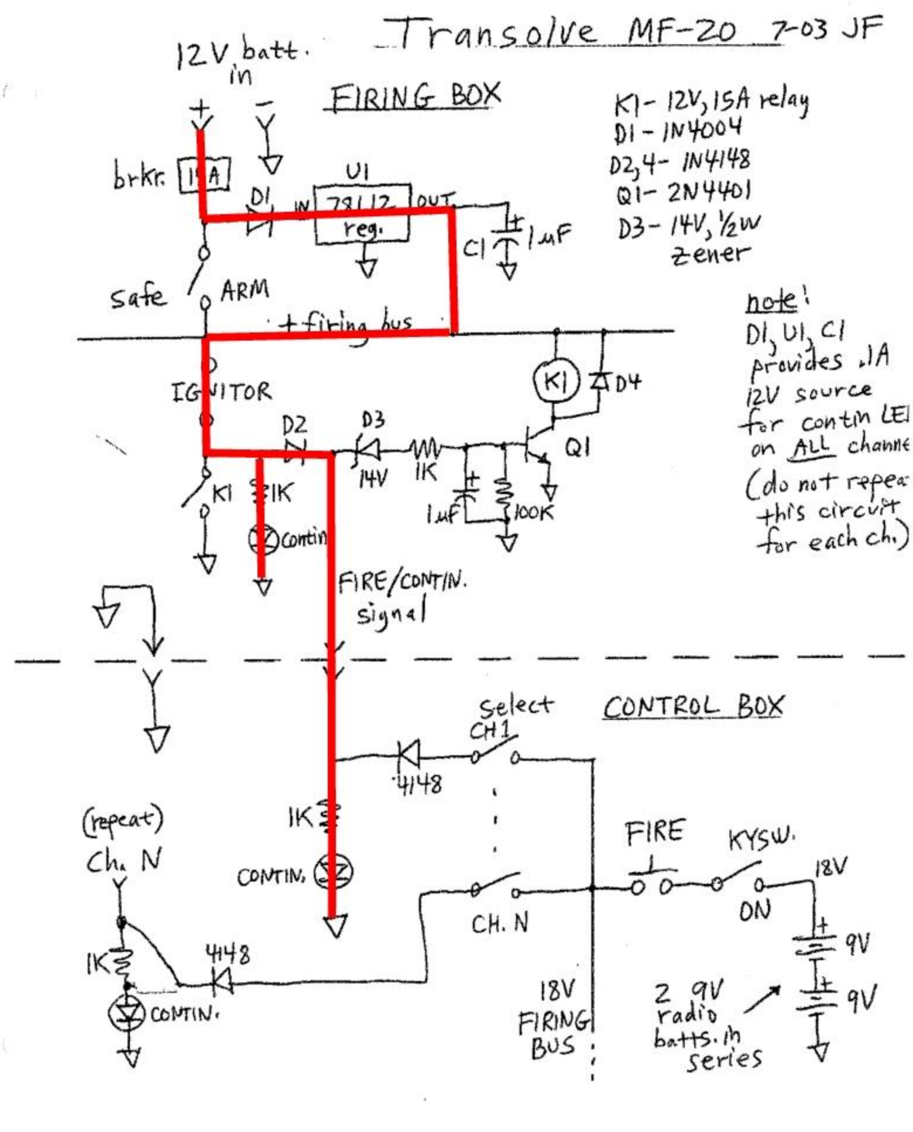

Figure 2: Firing Box Safe Mode Continuity Check Current Path

If the Firing Box has been placed in SAFE mode (the Firing Box ARM/SAFE switch is in the SAFE, or open, position), then continuity check current is provided by means of semiconductor U1, a 12V 78L12 linear voltage regulator. The voltage regulator is used in this application not as a regulator but as a current limiter; its maximum output current is 100 mA, and if the load is greater than this the device will overheat, and an internal thermal detection circuit will shut it down. The regulator also has on board short circuit protection, which likewise will also shut the device off if a short is detected. Therefore, with the Firing Box in SAFE mode there is no available current path that will provide sufficient current to activate an igniter should the Launch Button on the LCO Console be pressed.

The Firing Box's local 12V automotive ignition battery, when fully charged, can have a value of about 13.2V. The voltage at U1 pin 3 (the output pin) will then be about 11.0 volts. Not shown is a protection diode that is in series with the output of U1 and connected to the Firing Bus. This diode, when forward biased, will have a voltage drop of about 0.7V. The continuity check LEDs have a forward voltage drop of about 1.8V when forward biased. Diode D2 is a blocking diode and prevents the LCO Console 9 volt batteries from being shorted circuited to Ground during a launch event (Launch pushbutton depressed). However, Diode D2 is forward biased when an igniter is present, and in this state will have a voltage drop of about 0.7V. We can therefore calculate the continuity check current when the Firing Box is in SAFE mode, as follows.

For the local Firing Box Continuity LED:

$$\frac{(11.0V - 0.7V - 1.8V)}{1K} = 8.5\ mA$$

For the LCO Console Continuity LED:

$$\frac{(11.0V - 0.7V - 0.7V - 1.8V)}{1K} = 7.8\ mA$$

Therefore, the maximum **total continuity check current** flowing through an igniter when the Firing Box is in **SAFE** mode is the sum of these two values, or **16.3 mA**. This current level is safely compatible with most commercial model rocket igniters available on the market today; however, Fliers are well advised to be sure about the safe check current limits for the igniter or electric match they intend to use to launch their rocket. Failure to respect this system-imposed check current level could result in an unexpected and unsafe launch event while connecting igniter leads to a rocket.

If the Firing Box is placed in ARM mode then U1 is bypassed, and continuity check current is sourced directly from the ignition battery. Figure 3 illustrates this continuity check current path:

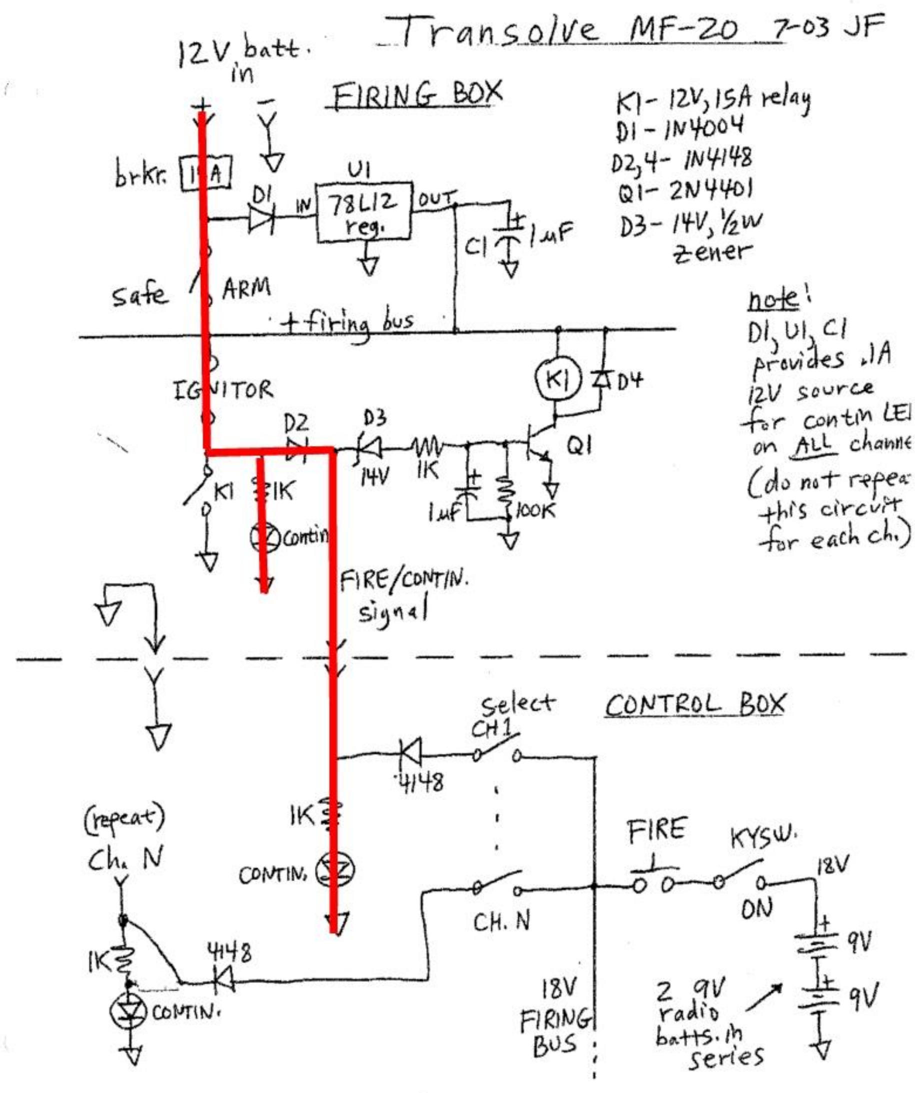

Figure 3: Firing Box ARM Mode Continuity Check Current Path

We can therefore calculate the continuity check current when the Firing Box is in ARM mode, as follows.

For the local Firing Box Continuity LED:

$$\frac{(13.2V - 1.8V)}{1K} = 11.4\ mA$$

For the LCO Console Continuity LED:

$$\frac{(13.2V - 0.7V - 1.8V)}{1K} = 10.7\ mA$$

Therefore, the maximum **total continuity check current** flowing through an igniter when the Firing Box is in **ARM** mode is the sum of these two values, or **22.1 mA**. This current level is safely compatible with most commercial model rocket igniters available on the market today; however, Fliers are well advised to be sure about the safe check current limits for the igniter or electric match they intend to use to launch their rocket. Failure to respect this system-imposed check current level could result in an unexpected and unsafe launch event while connecting igniter leads to a rocket.

Diode D3 is a 14V Zener diode; it blocks the Ignition Battery from activating the firing circuit as it will only conduct when the voltage at its cathode is 14V or greater.

Not shown in the overview schematic is the Continuity switch located on the LCO Console. It is wired in series between Ground and the return from each LCO Console Continuity LED indicator. When off, the Console LEDs are disabled; when the switch is on, the Console LEDs will light when igniters are hooked up into the system.

Note that this switch only affects the LCO Console LEDS; the local LEDs on the Firing Box will continue to light irrespective of the position of this switch.

Also note that flipping the Continuity switch does not activate the continuity check. In this circuit design, continuity is automatically detected once an igniter is inserted into the circuit. The Continuity switch only allows the opportunity for the indication to be presented at the Console.

The reason why this switch was added to the Console was to further limit the possible current drain on the 9V control batteries in the LCO Console. The circuit is such that when the LCO Console FIRE pushbutton is pressed, current from the 9V batteries will flow through the LCO Console Continuity LEDs of the pad(s) that has/have been enabled for operation. Figure 4 illustrates this sneak current path:

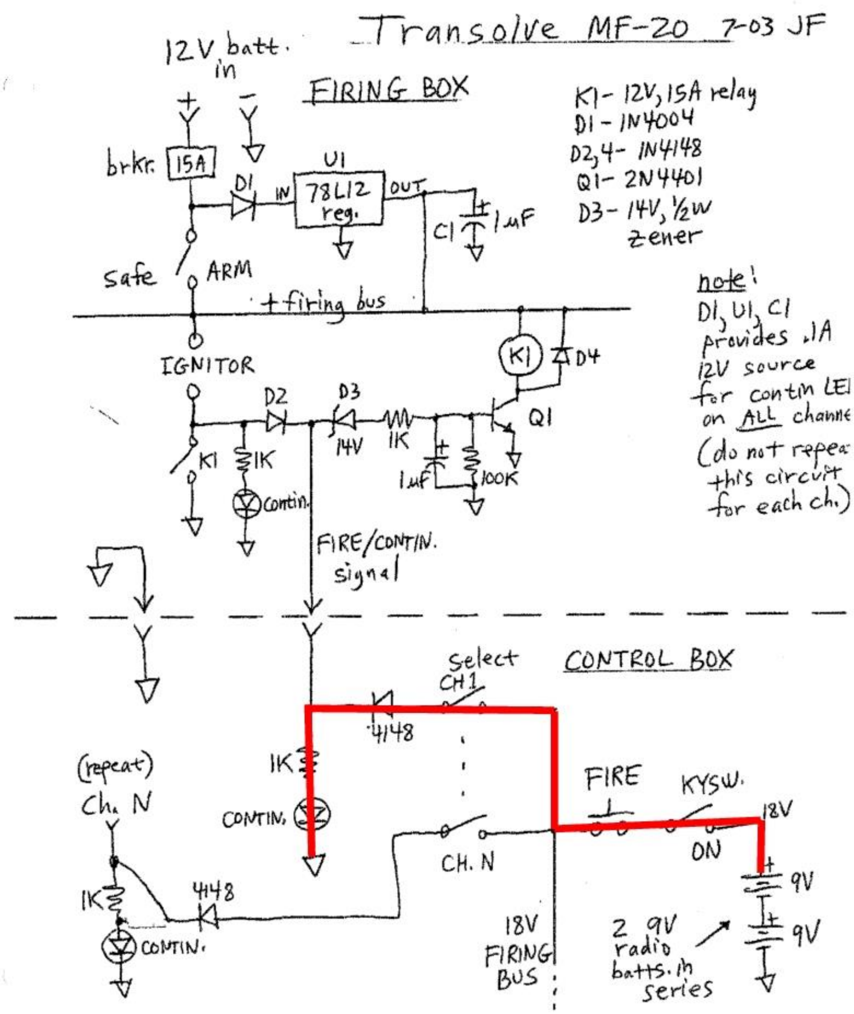

Figure 3: LCO Console Continuity Sneak Current Path

This current (per enabled Pad), even though momentary, can be calculated as follows:

$$\frac{(18V - 0.7V - 2V)}{1K} = 15.3\ mA$$

This is in addition to the current drawn from these batteries for each firing circuit (see next section). So Transolve added the LCO Console Continuity switch so that the LCO Console LEDs could be disconnected from the control circuit to save control battery power. Had Transolve chosen to use a double pole FIRE pushbutton, then the second pole contacts could have been used for this purpose, which would automatically disconnect the LEDs from the control circuit any time the pushbutton is pressed; this would save the added Continuity Check switch on the control panel (and likely some operator confusion).

System ARMed – LCO Console Key Switch Turned to the "ON" Position

Figure 4 illustrates the Firing Circuit control path when the Launch pushbutton is pressed. Note that this represents just one enabled pad; this path is replicated for each pad circuit that has been enabled for operation.

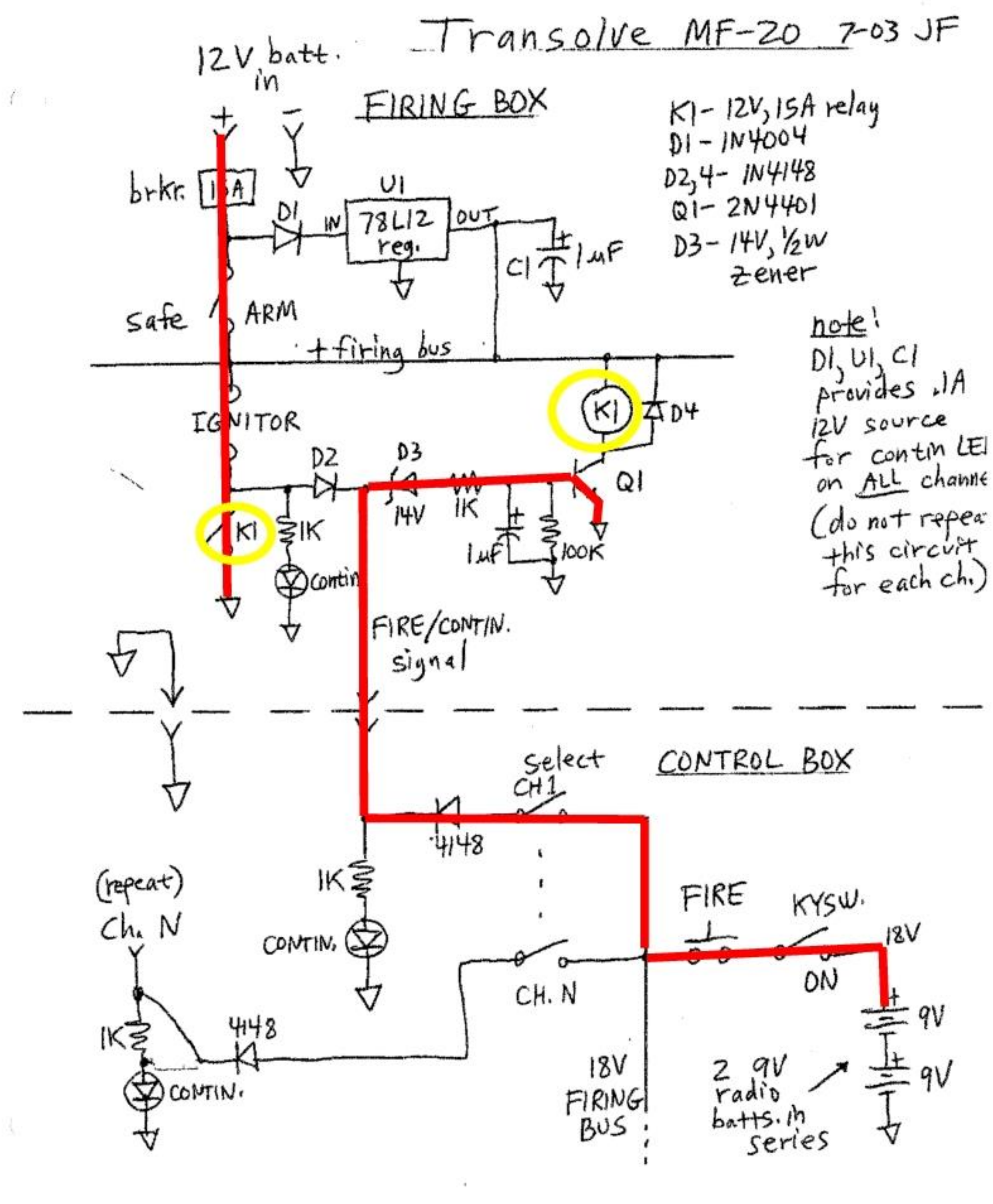

Figure 4: Firing Circuit Control Path

Note that the firing control circuit is powered by the two 9 volt batteries located within the LCO Console. These batteries are wired in series, presenting a total control voltage of 18 volts to the control circuit.

Highlighted in Yellow is the ignition relay; there is a dedicated ignition relay for each individual pad/igniter in the system. The relay is controlled by a transistor drive circuit, but the relay contact K1 is in direct series between the igniter and Ground. When the ignition relay is picked, KI contact closes an extremely low impedance current path, essentially shorting the ignition battery through the igniter to Ground. The resulting high current level (limited only by wire and contact resistances) will quickly heat, and then burn out, the igniter, hopefully leading to a successful launch event.

Ignition relay K1 is controlled by the transistor drive circuit, its active elements being D3 (the 14V Zener Diode) and Q1, a general purpose NPN transistor biased to saturate (i.e.: function as a switch) when energized. The firing control circuit can only turn on when the LCO Console is ARMed (Key Switch is in the "ON" position), a pad or pads has/have been selected (Console pad switches turned "ON"), and the FIRE pushbutton is pressed.

When these conditions are met, the control circuit voltage is presented to the cathode of D3, the 14V Zener diode. As the applied voltage is greater than 14V, the Zener breaks down (turns on), presenting a voltage of (18V – 0.7V – 14V) = 3.3 V at the 1K transistor Base resistor. This is enough to bias Q1 on (its Base-Emitter drop ~ 0.8V), the base current being:

$$\frac{(3.3V - 0.8V)}{1K} = 2.5\ mA$$

With Q1 turned on, K1 picks, and the ignition sequence occurs as described earlier. The same firing path occurs for every pad that is selected/enabled; if all 10 pads were involved in a drag race, for example, then the total current draw for firing that launch event would be 25 mA.

A few words about the remaining components within the transistor drive circuit:

Diode D4 is a back EMF shunting diode placed across the coil of the relay. This diode protects the transistor's Collector-Emitter junction from harmful reverse voltage caused by the collapsing magnetic field in the relay's coil when the relay is turned off. Without D4 there is a risk the transistor's collector junction would break down, leading to permanent transistor damage.

The 100k resistor placed in parallel (i.e.: a shunt resistor) to the transistor's Base-Emitter junction is there to ensure that the transistor fully turns off when power is removed from the Base. Without this, the transistor's input could float, possibly allowing current to flow through the Collector-Emitter junction; certainly more possible with the type of high impedance relay used in the circuit. The shunting capacitor is there to both smooth and prolong the turn on of Q1.