Tucson Garden Railway Society

Tucson Botanical Garden

Train Control System

Date: July 2019

GEM 06/2020

TBG Train Control System

Introduction

In mid-2019 the control system for the TGRS train display at Tucson Botanical Garden (TBG) was updated as part of an overall layout refurbishment. The general scheme of the display is two independent loops of track. A train shed was installed to house the trains while not in use. And, a train control system was developed that, once started, would allow the trains to run around the loops three times and then stop inside the train shed. At this time the layout is set up for both trains to run in a clockwise direction around the loops. The START switch starts both trains. If one train is already (still) running, the other will start. If both trains are running, the START switch has no effect.

This document is a “90%” definition of the control system for the TBG layout. It contains the circuitry and micro controller programs, as well as most of the electronic parts definitions. It does not include details for: mechanical parts, data sheets or info for common parts (resistors, capacitors, LEDs, etc.) or connectors. Many of those items came from extra or spare parts that were on-hand.

Abbreviations (in no particular order)

IL – inside loop of track
OL – outside loop of track
DB – display panel and the circuit board mounted to it’s under side
KBD – relay board (main board inside the electronics enclosure)
WDT – watchdog timer
E/D – enable/disable
IR – infrared

Notes

1. The trains are powered by Bridgewerks Magnum 5-SR power supplies. These power supplies have a remote input function that allows the voltage to the track to be turned On/Off by the control system. When the START switch is activated, the control system opens the Remote Input terminals of the 5-SR which allows the track voltage to rise to the level set by the slide control. When the trains are to be stopped in the engine shed, the control closes the Remote Input terminal and the track voltage drops to zero. Also, the 5-SR has a momentum function which should be turned “On” for normal operation. This increases and decreases the track voltage smoothly which helps the locomotive drive trains to last longer.
2. The control system works using magnetic reed switches just inside the entrance end of the engine shed to detect the arrival / passing of a train. To trigger the reed switch, each loco must have a magnet attached to its bottom center. LGB 17010 magnets work well for this function. Other magnets can be used but make sure they actually activate the reed switch when the train passes.
3. The WDT function monitors the elapsed time of each train cycle around the loop. If a train takes too long to complete a loop (return to the engine shed), the WDT expires and the controller shuts power off to that loop. Currently, this time is approximately 100 seconds. Also, as currently implemented, if/when the START switch is activated the expired WDT will be reset and power applied to that loop again.
4. There are currently three micro controllers that implement the control logic. All three are Picaxe controllers from Revolution Education Ltd. In the UK. For more Picaxe information and documentation, go to https:\\picaxe.com. One source for Picaxe is Sparkfun Electronics (www.sparkfun.com). The following are the Picaxe chips used:
    - Overall logic and control – 18M2 (on a CHI030A project bd)
    - WDT – 08M2+ (on an Axe021 proto bd)
    - IR START Switch – 08M2+

TBG Train Control System

Photos

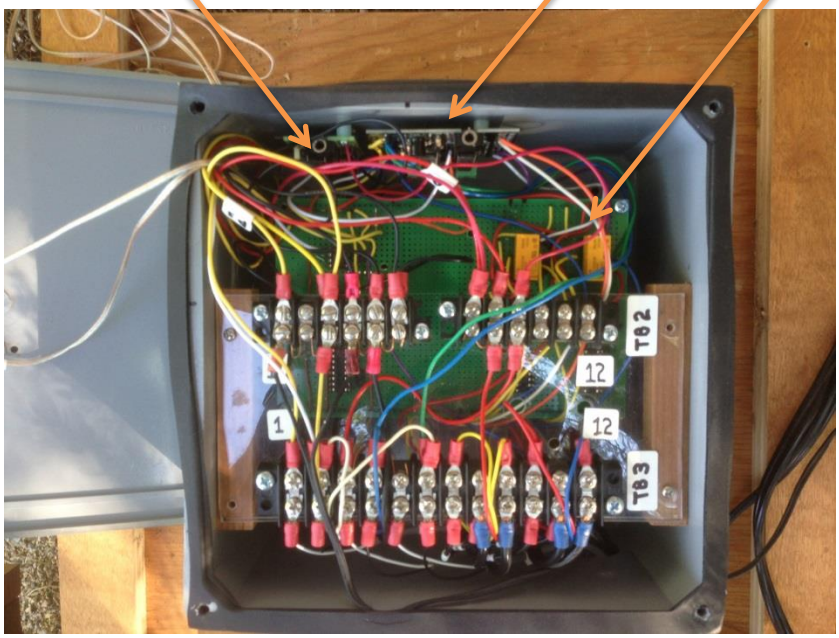
Overall Layout

Electronics Enclosure

WDT (AXE021)

CH1030A

START/STOP Relays



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Display Board Functions

The Display Board is the primary interface for the operator. It provides visual feedback on the operation of the trains and provides inputs to the system to simulate the trains traveling around the loops. This may be helpful during trouble shooting. The following items describe the functions of the Display Board switches and LEDs:

Display Board switches and indicators – Automatic Mode Only.

The board is divided into three areas: common to both track loops, the Inside track loop and the Outside track loop.

The common area at the top of the Board:

- START Switch and LED – The START switch is in parallel, and preforms the same function as, the START switch on the post used by visitors to start the trains. The START switch starts both trains. If one train is already (still) running, the other will start. If both trains are running, the START switch has no effect. The START LED will light when either START switch (post or panel) is pressed indicating the switch is functioning.
- RESET Switch – The RESET switch has NO function at this time.
- 12v & 5v LEDs – These LEDs indicate that the DC power to the system is functioning. If either or both are not ON, there is a problem with the power to the control system and AUTO Mode will not function.

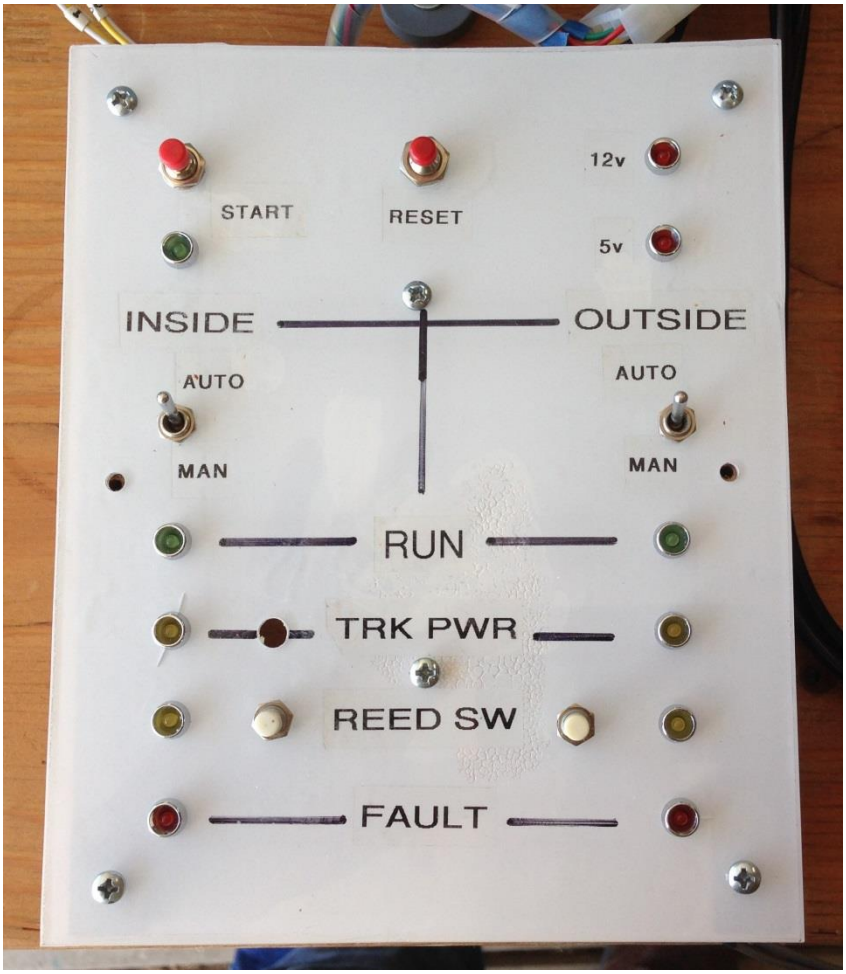
The INSIDE and OUTSIDE loop areas:

- AUTO/MAN Switch – selects AUTO Mode (train controlled by the control system) or Manual Mode (train manually controlled directly from the train power supply).
- RUN LED - Lights when the control system is commanding the power supply to power the track.
- TRK PWR – Lights when power is being supplied to the track (at TB1 track connections).
- REED SW LED and pushbutton – lights when the train (magnet on engine) passes over the reed switch mounted on the track in the engine shed. The pushbutton switch preforms the same function as the reed switch – the control system “thinks” the train has just passed over the reed switch.
- FAULT LED - At this time the FAULT LED has two functions:

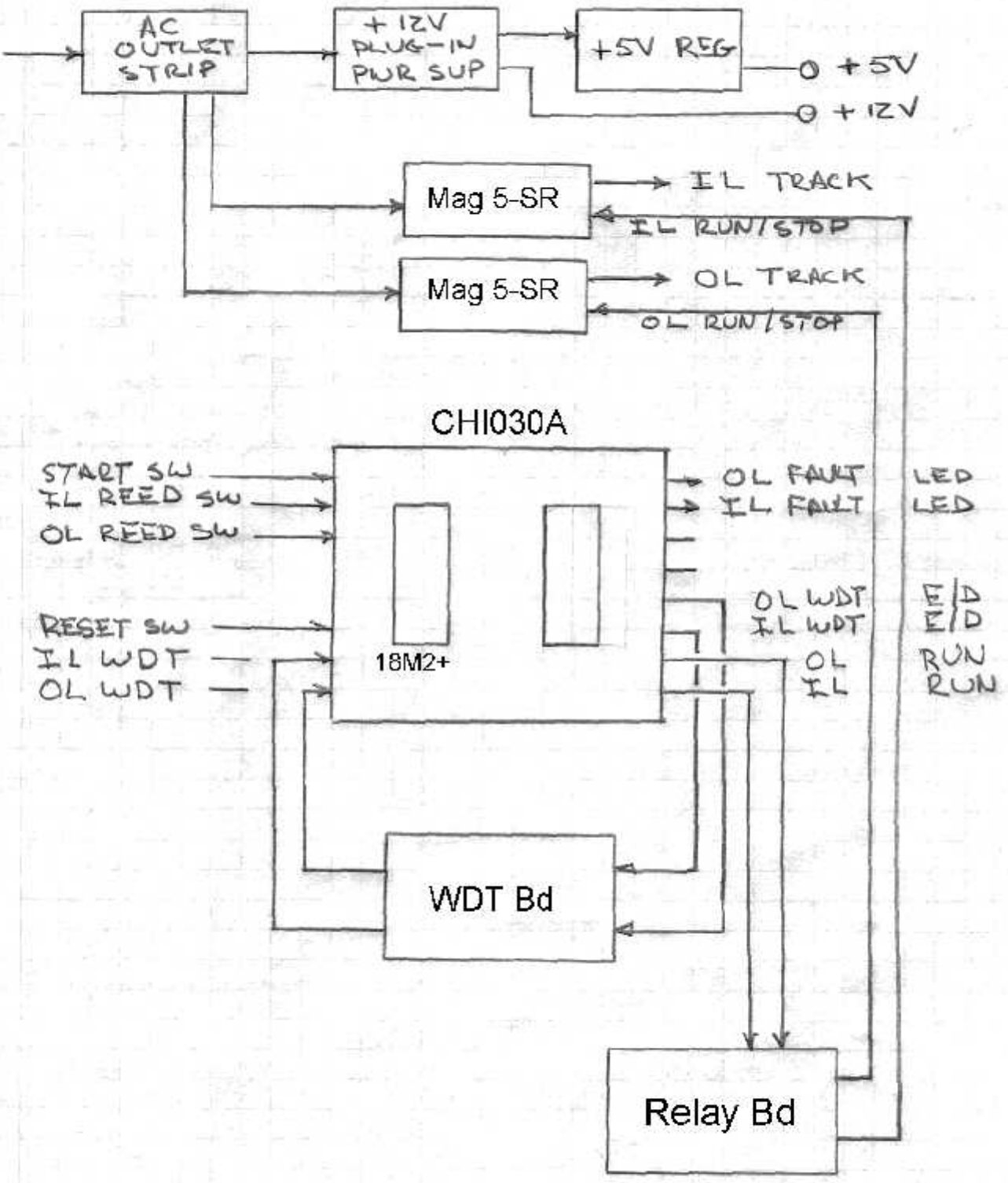
  If ON constantly, it means the train is in its last circuit around the track before stopping in the engine shed. If FAULT is flashing, then the train has not completed a circuit of the track in the expected time (derailment, etc.). Currently, when the START switch is pressed again, the train will restart. (Hopefully, after the derailment/problem has been fixed.)

TGB Train Control System

Display Board



TBG Train Control System Block Diagram



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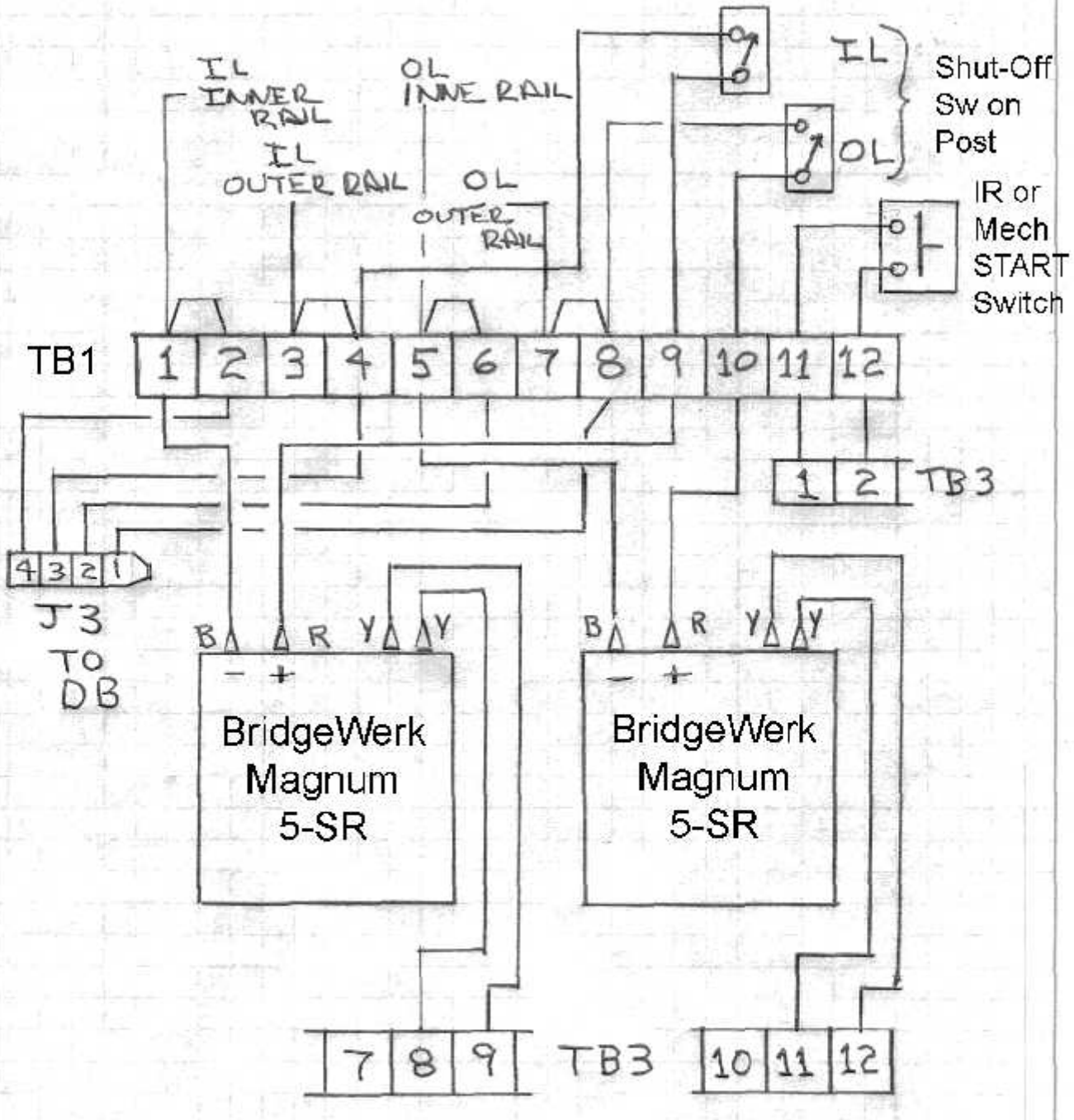
Train Pwr Wiring (TB1)



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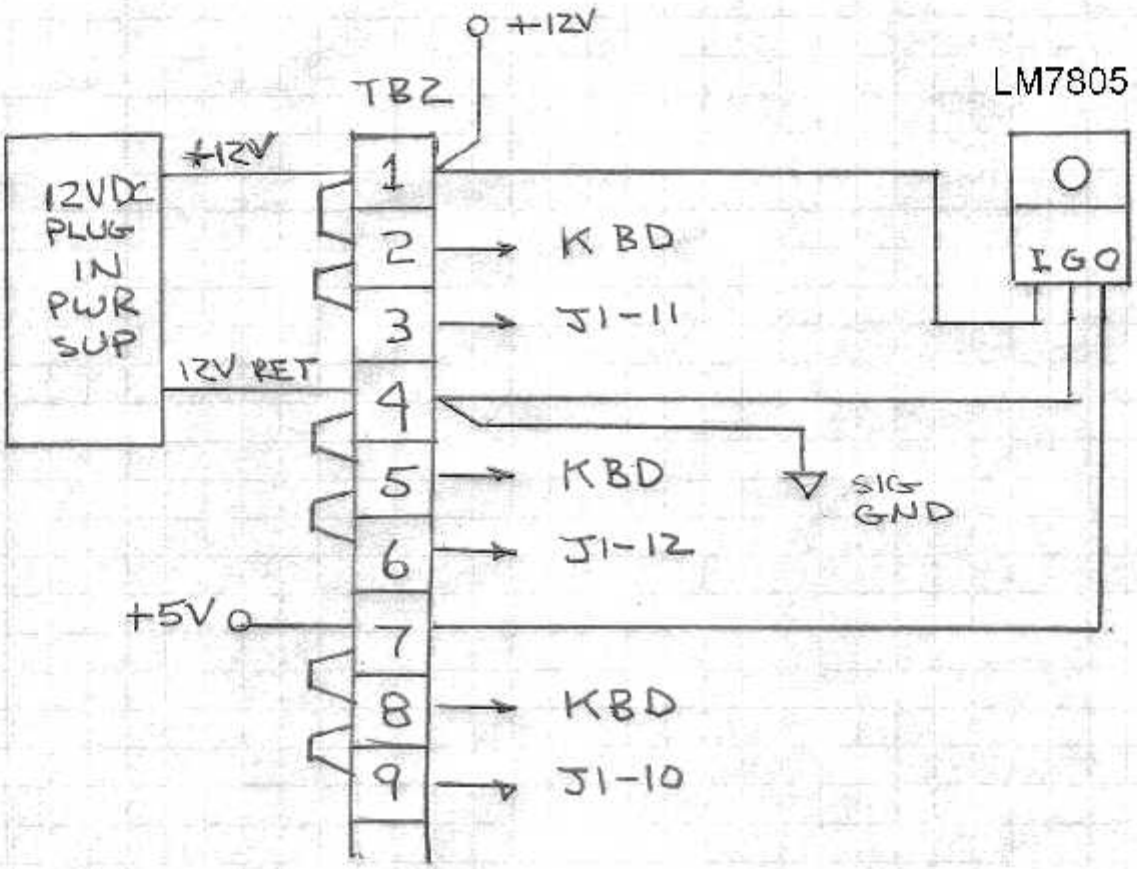
DC Power



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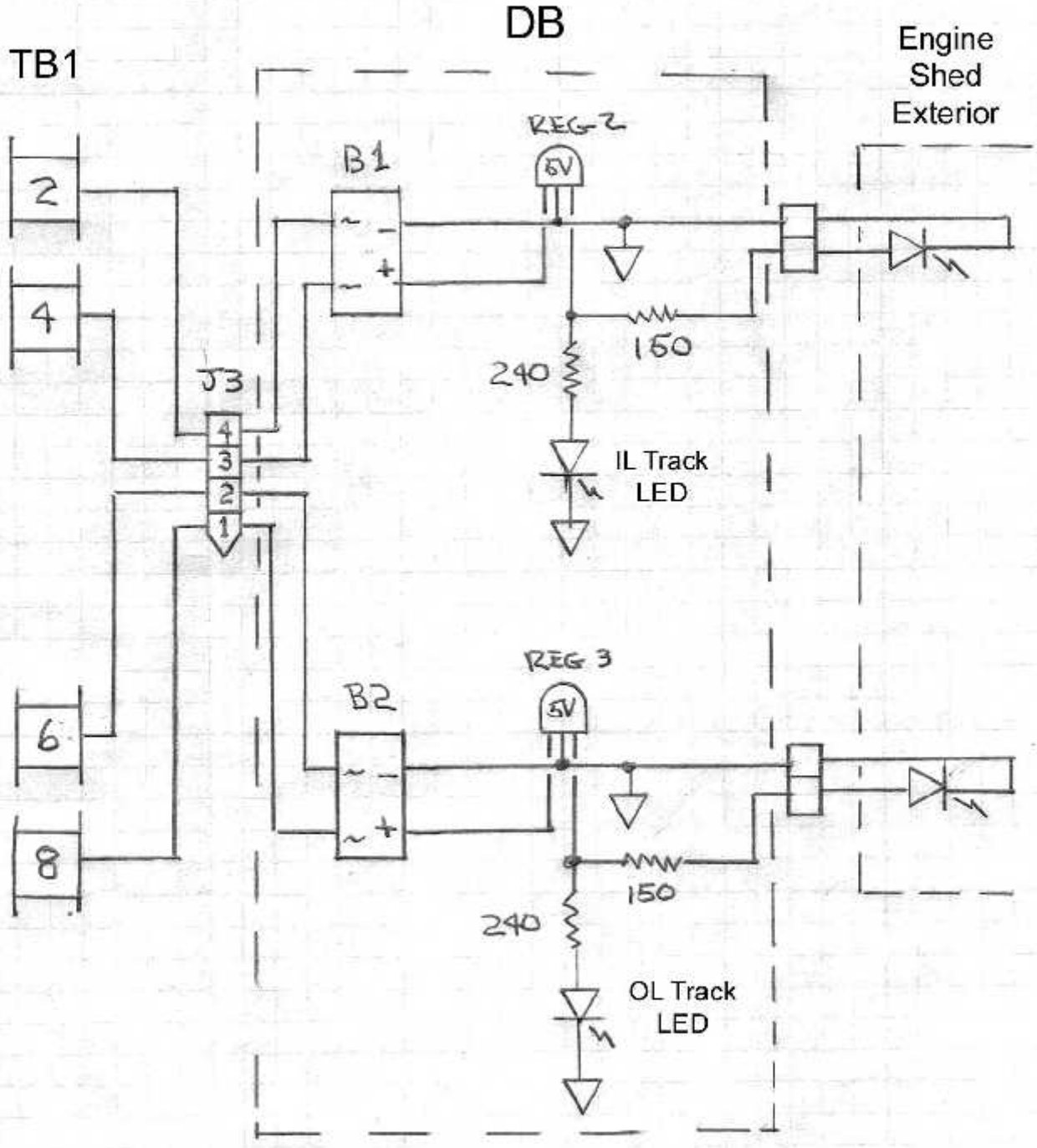
Track Power LEDs



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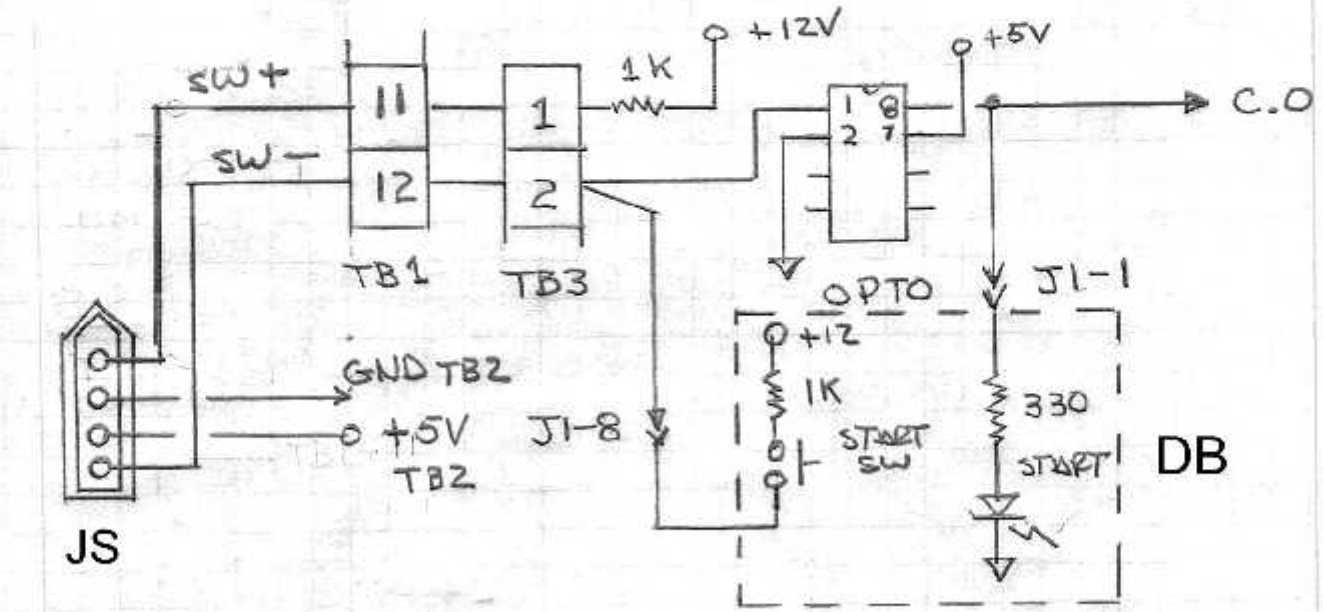
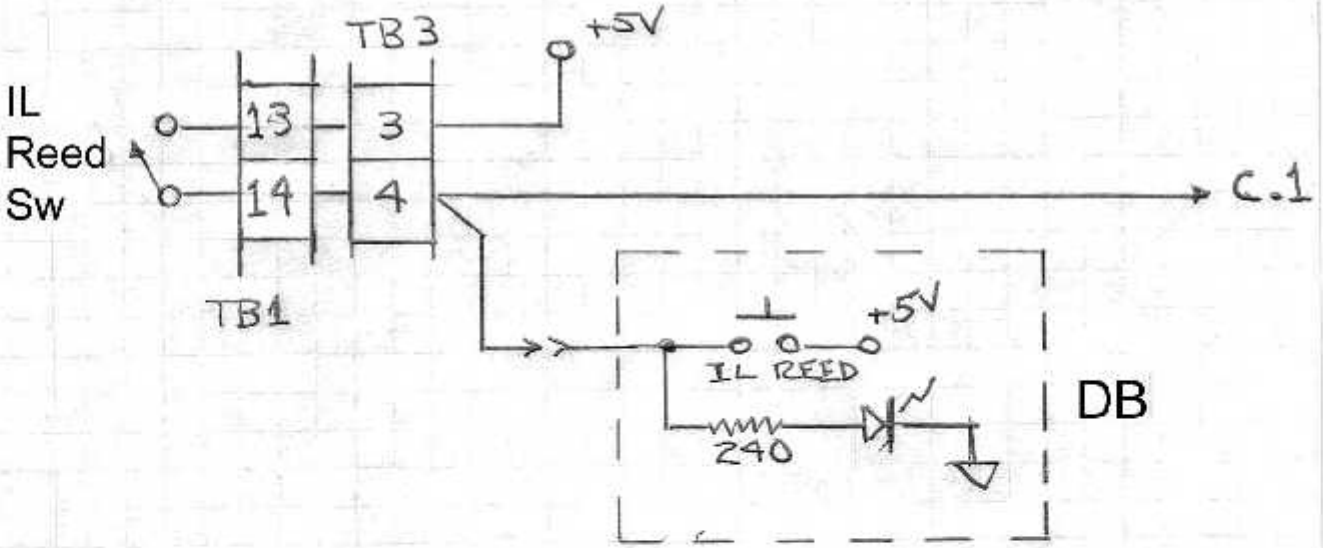
Inputs - Start Sw, Reed Sw





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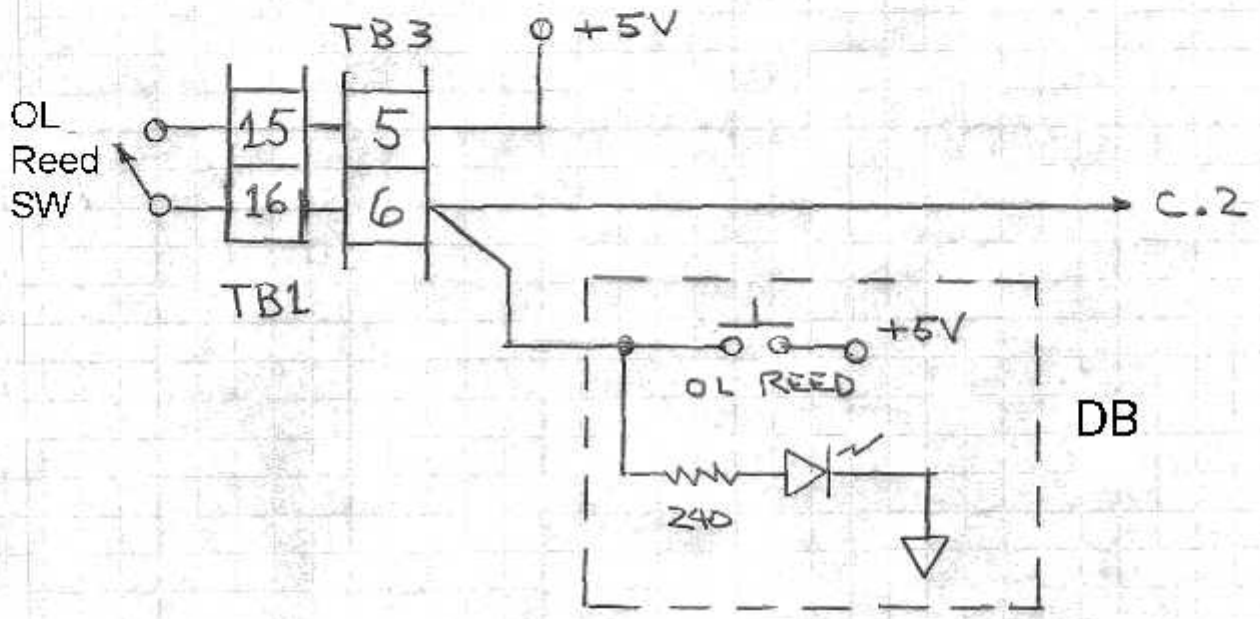
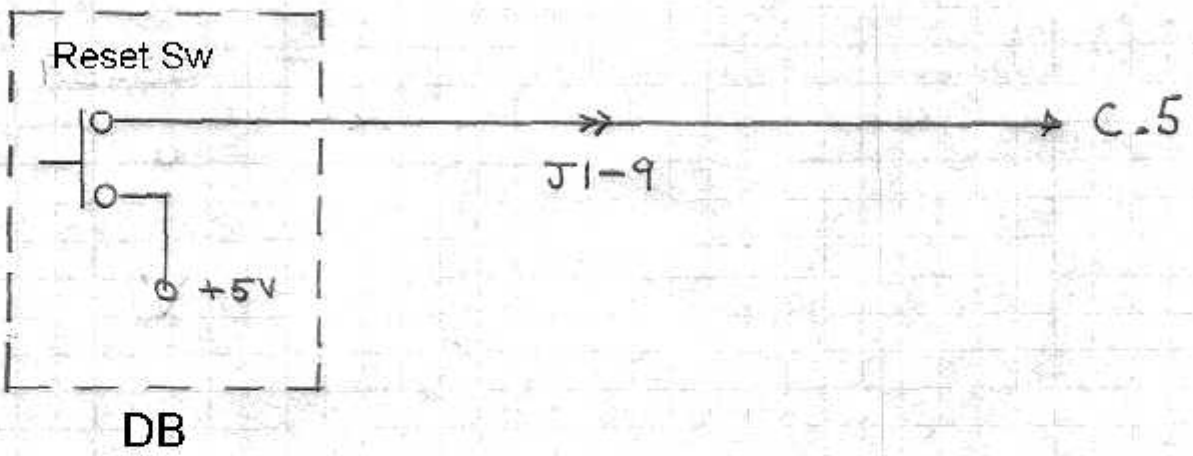
Inputs 2





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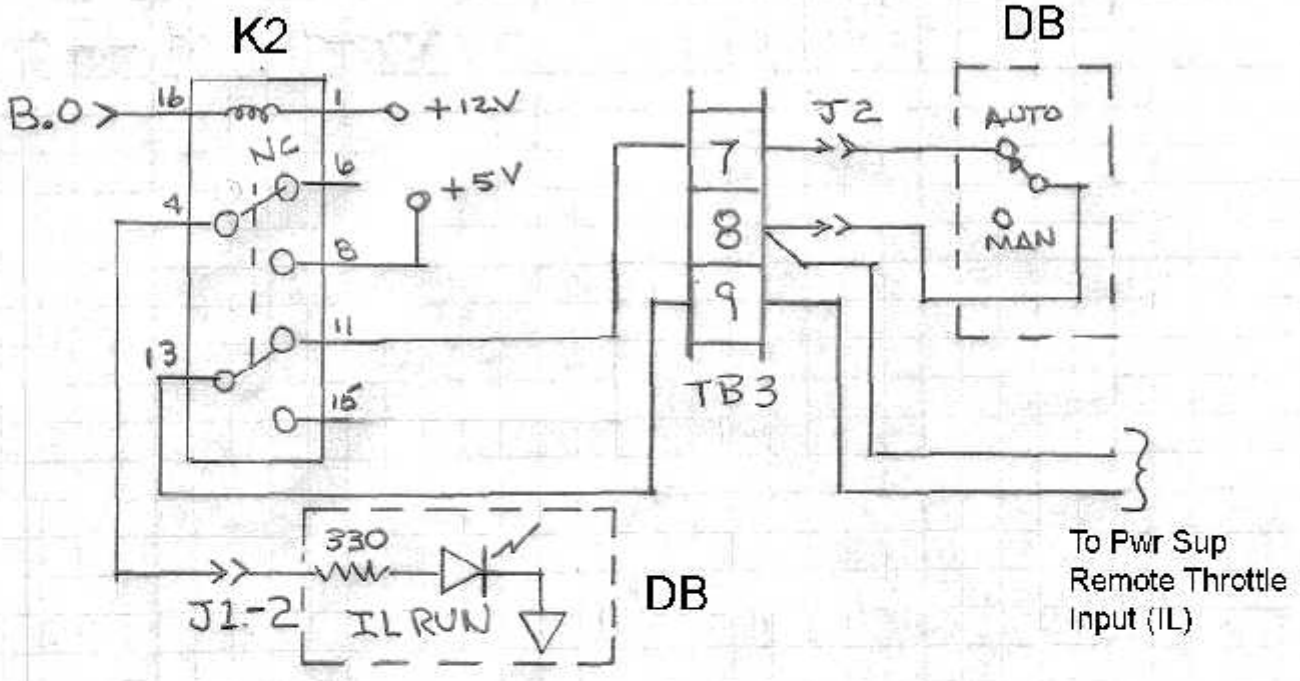
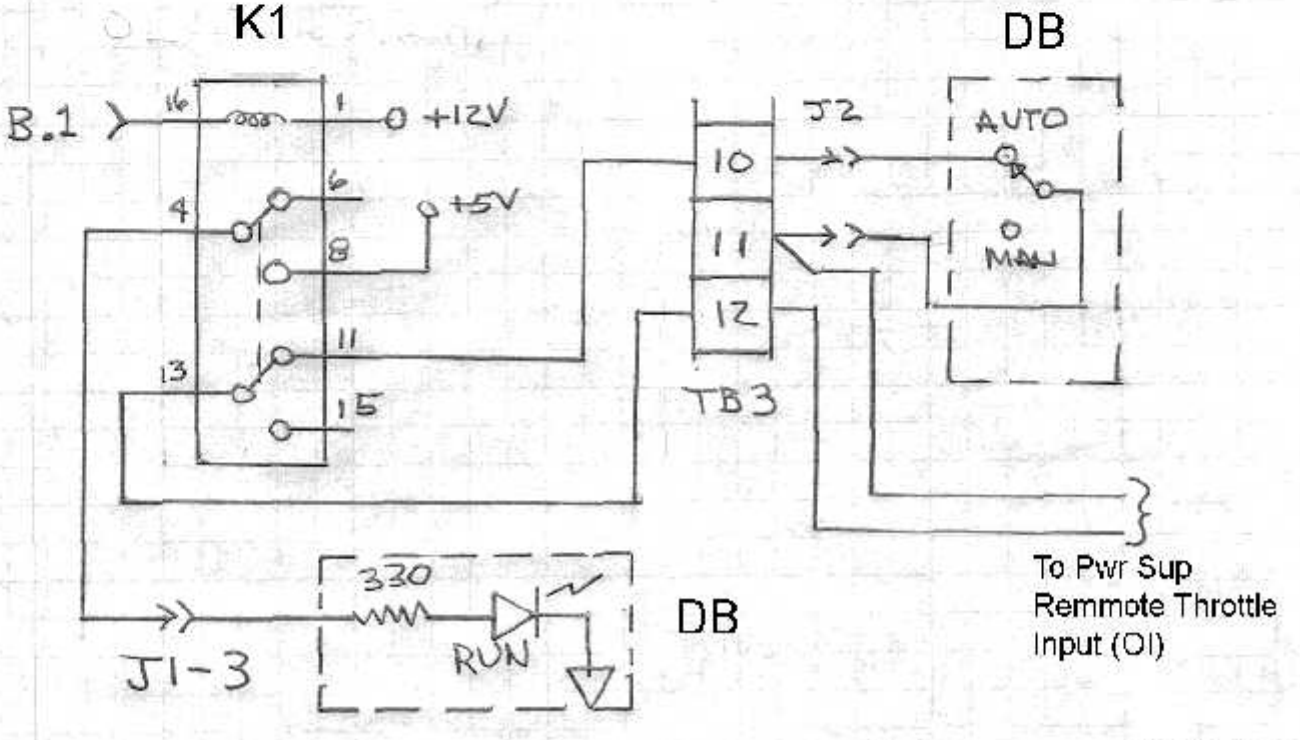
TBG Train Control System Outputs - RUN Relays





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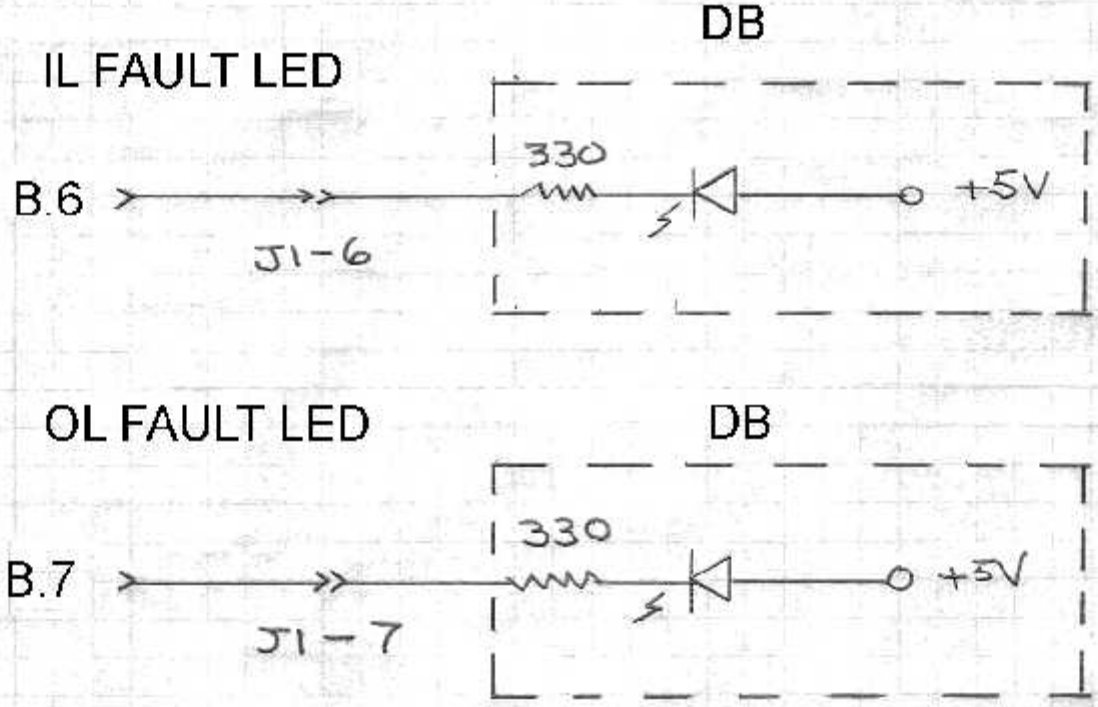
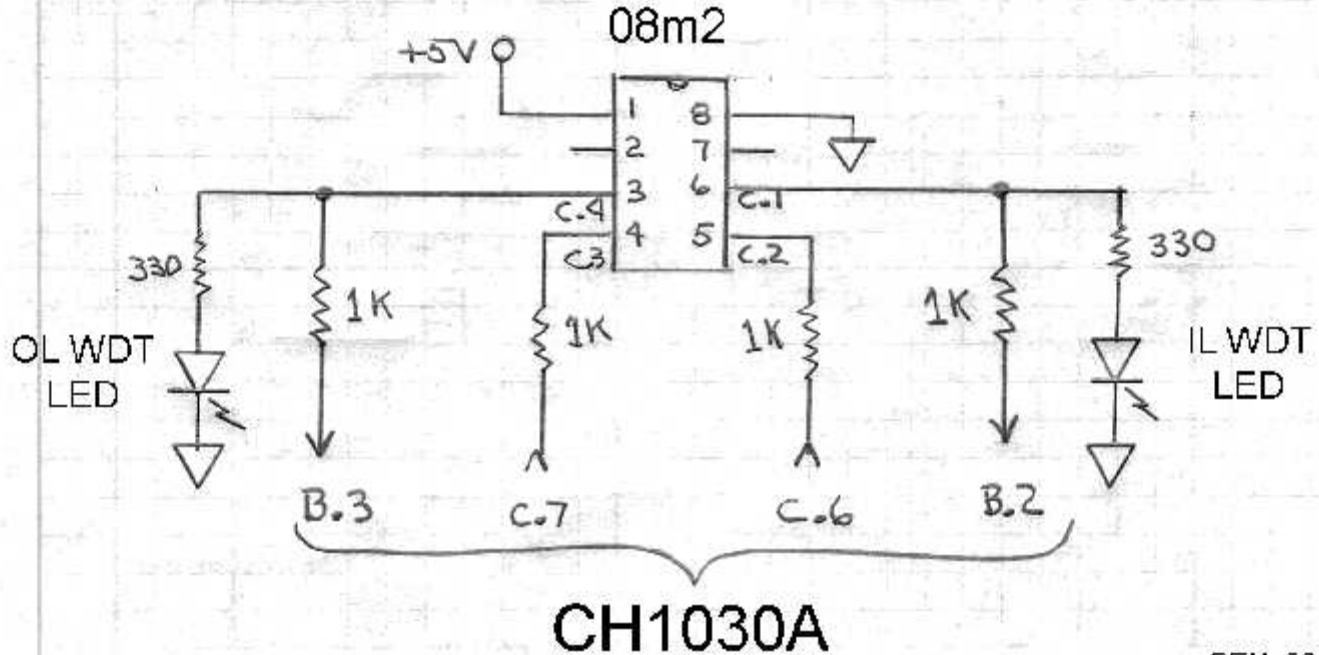
TBG Train Control System Outputs, WDT



Watchdog Timer (WDT)

On AXE021 proto board



CH1030A

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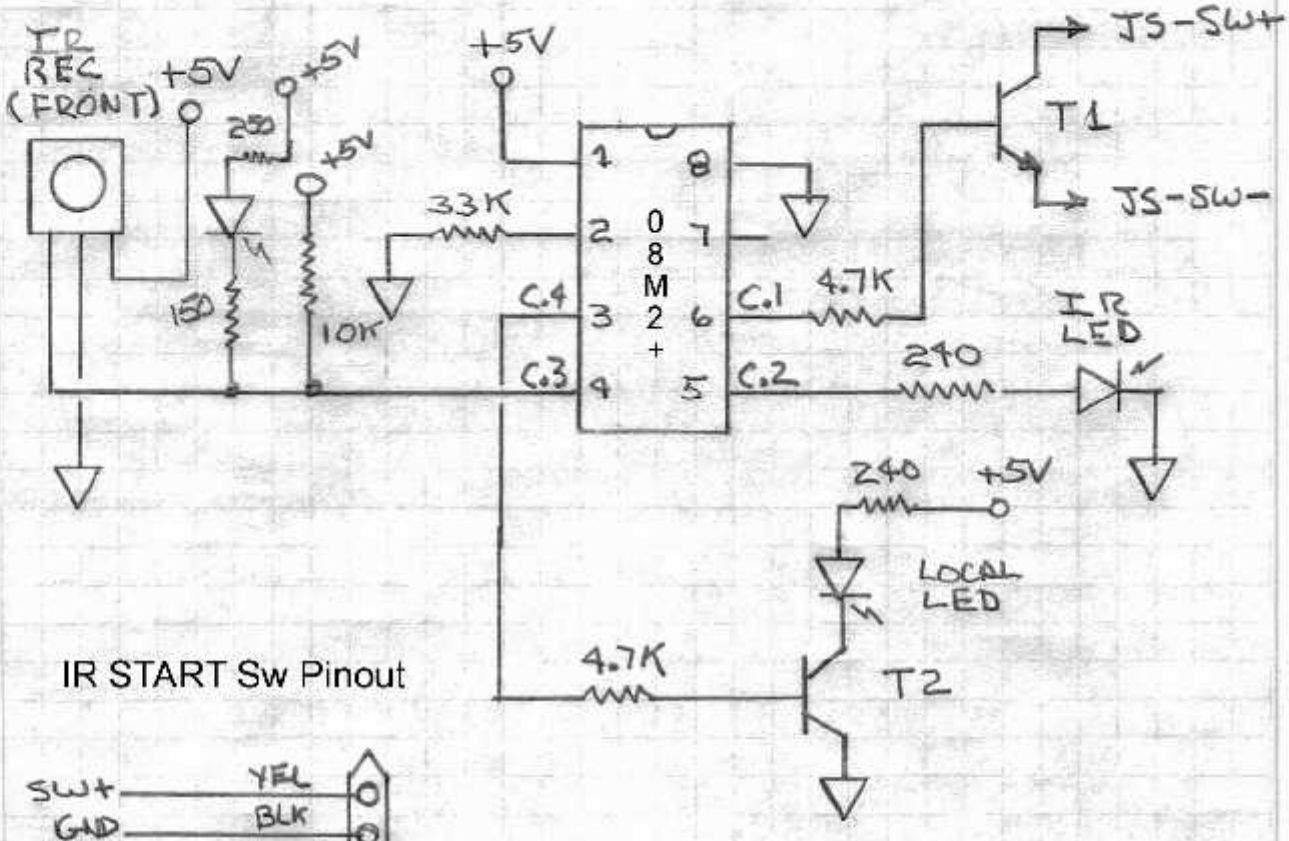
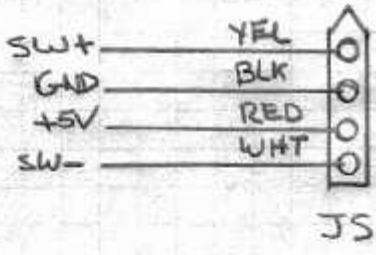
TBG Train Control System START Switch

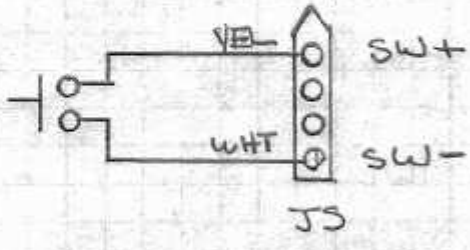
IR START Sw Circuit



IR START Sw Pinout



Mech START Sw Pinout



Connector JS in Start Sw junction box on "post"

TBG Train Control System

Picaxe Input / Output Pin Assignments

CHI030A Inputs

Pin Designation	Function	Note
C.0	START Switch	High (1) = Start
C.1	Inside Loop Reed Switch	High (1) = Reed Sw Triggered
C.2	Outside Loop Reed Switch	High (1) = Reed Sw Triggered
C.5	Reset Switch	High (1) = Reset ON
C.6	Inside Loop WDT	High (1) = WDT timed out
C.7	Outside Loop WDT	High (1) = WDT timed out

CHI030A Outputs

Pin Designation	Function	Note
B.0	IL RUN Relay	High (1) = RUN
B.1	OL RUN Relay	High (1) = RUN
B.2	Inside Loop WDT E/D	High (1) = Enable
B.3	Outside Loop E/D	High (1) = Enable
B.4	Not used	
B.5	Not used	
B.6	IL FAULT led	High (1) = ON
B.7	OL FAULT led	High (1) = ON

WDT (08M2+) Inputs & Outputs

Pin Designation	Function	Note
C.1	Inside Loop WDT Out	High (1) = WDT Expired
C.2	Inside Loop WDT E/D In	High (1) = Enable
C.3	Outside Loop WDT E/D in	High (1) = Enable
C.4	Outside Loop WDT Out	High (1) = WDT Expired

IR Start Switch (08M2+) Inputs & Outputs

Pin Designation	Function	Note
C.1	START Switch Out	High (1) = START
C.2	Output to IR LED	38K Hz pulse train (pwm)
C.3	IR Input, from IR Detector	Low (0) = reflected IR Present
C.4	Local LED Out	High (1) = LED On

```
01
02
03
04    ;TBG TRAIN CONTROL
05
06    ;Main Train Control Program
07    ;Piceaxe 18M2+ Chip on the CH1030A Proto Bd
08
09
10
11    start0:                       ;Inside loop program
12          symbol iloops = b6
13          iloops = 3          ;# of loops inside train makes before stop
14
15    istsw:      if pinc.0=0 then istsw  ;wait for START switch
16    a3:   high b.0            ;set to RUN
17          low b.2                 ;disable Iloop WDT
18          b0=0                ;b0 is inside loop counter
19          b1=iloops-1
20          pause 2000          ;wait for train to get started
21    irdsw:      if pinc.1=1 then a1     ;watch for inside reed switch
22          high b.2            ;Enable iloop WDT
23          if pinc.6=1 then goto iEstp   ;watch for inside WDT
24          pause 50
25          goto irdsw          ;go to beginning of watch loop
26    a1:   low b.2                 ;disable Iloop WDT
27          inc b0                  ;increment loop counter
28          if b0 >= iloops then istp     ;test loop counter
29          if b0=b1 then ifon
30    a2:   pause 1000
31          goto irdsw          ; go back to watch loop
32
33    istp: low b.0                 ;STOP
34          low b.2                 ; Disable iloop WDT
35          low b.6                 ;iFault Off
36          pause 1000
37          goto istsw          ;go back to START switch
38
39    iEstp:      low b.0               ;STOP
40          low b.6
41    a4:   if pinc.0=1 then goto a3      ;test for START switch
42          high b.6            ;"FAULT" on
43          pause 300
44          low b.6                 ;"FAULT" off
45          if pinc.0=1 then goto a3      ;test for START switch
46          pause 600
47          goto a4
48
49    ifon: high b.6
50          goto a2
51
52
53    start1:                       ;Outside loop program
54          symbol oloops = b7
55          oloops = 3
56
57    ostsw:      if pinc.0=0 then ostsw
58    a13:  high b.1            ;set to RUN
59          low b.3                 ;disable oloop WDT
60          b2=0
61          b3=oloops-1
62          pause 2000
63    ordsw:      if pinc.2=1 then a11
64          high b.3            ;Enable oloop WDT
65          if pinc.7=1 then goto oEstp
66          pause 50
```

```
67          goto ordsw
68    a11:  low b.3
69          inc b2
70          if b2 >= oloops then ostp
71          if b2=b3 then ofon
72    a12:  pause 1000
73          goto ordsw
74
75    ostp: low b.1                 ;STOP
76          low b.3                 ; Disable iloop WDT
77          low b.7                 ;iFault Off
78          pause 1000
79          goto ostsw
80
81    oEstp:      low b.1                 ;STOP
82          low b.7
83    a14:  if pinc.0=1 then goto a13
84          high b.7
85          pause 300
86          low b.7
87          if pinc.0=1 then goto a13
88          pause 600
89          goto a14
90
91    ofon: high b.7
92          goto a12
93
94
95
```

```
01
02
03
04
05
06
07    ;TBG TRAIN CONTROL
08
09    ;Watchdog Timer (WDT) Program
10    ;Picaxe 08M2+ on the 08 Proto Bd
11
12                                  ;pin C.1 - IL WDT Out (1 = WDT timed out)
13                                  ;pin C.2 - IL WDT Enable / Disable In (0 = Disable)
14
15    start0:                             ;Watch Dog Timer for inside loop
16          b4=100                        ;# of 1 sec intervals
17          low c.1
18    a1:   if pinc.2=0 then a1           ;IL WDT Enabled?
19          low c.1                       ;set IL WDT Out off
20          for b0=1 to b4                ;start WDT timing loop
21                pause 1000
22          if pinc.2=1 then goto a2      ;check IL E/D
23          goto start0             ;if Disabled, stop timer and restart
24    a2:   next b0                       ;if Enabled, continue timing
25          high c.1                ;WDT timed out, set WDT output high
26    a3:   if pinc.2=1 then a3           ;wait for IL WDT to be Disabled
27          goto start0             ;restart
28
29
30                                  ;pinc.3 = OL WDT Enable / Disable In (0 = Disable)
31                                  ;pinc.4 = OL WDT Out (1 = WDT timed out)
32
33                                  ;Logic for Outside Loop same as Inside Loop
34
35    start1:                             ; Watch Dog Timer for outside loop
36          b5=100                        ;# of 1 sec intervals
37          low c.4
38    a11:  if pinc.3=0 then a11
39          low c.4
40          for b1=1 to b5
41                pause 1000
42          if pinc.3=1 then goto a12
43          goto start1
44    a12:  next b1
45          high c.4
46    a13:  if pinc.3=1 then a13
47          goto start1
```

```
01
02
03
04
05
06
07    ;TBG TRAIN CONTROL
08
09    ;IR START Switch Program
10    ;Picaxe 08M2+ Chip
11
12                ;pin c.1 = Start switch out - HIGH = Start sw ON
13                ;pin c.2 = output to IR led - 38 khz pulse rate
14                ;pin c.3 = input fron IR sensor - LOW (0) = IR signal detected
15                ;pin c.4 = output to local led - High = led ON
16
17
18    main:
19          pwmout c.2, 25, 52              ;start IR 38k output
20    a2:   if pinc.3 = 0 then a1           ;test for output from IR sensor
21          pause 2
22          goto main
23
24    a1:   high c.1                  ;activate start sw function
25          high c.4                  ;local led ON
26          pause 500
27          low c.1                         ;deactivate start sw function
28          low c.4                         ;local led OFF
29          pause 1000                ;delay before testing for IR out again
30          goto main
```

TBG Train Control System

REF	Qty	Description	Part # or Designation	Company	Notes
		Power Supplies			
	2	Train power supplies	Magnum 5-SR	BridgeWerks	
	1	Plug-in 12v DC Pwr Supply	SW15-12-N-P5	CUI Inc	500ma; Or equiv; avail from DigiKey
reg1	1	5 vdc voltage regulator	LM7805	various	
	various	filter caps, diode			
		Main Controller			
	1	Picaxe 18M Project Bd	CHI030A	Revolution Edu	from SparkFun Electronics
	1	Micro controller	18M2+	Revolution Edu	from SparkFun Electronics
opto	1	opto isolator	NTE3086	NTE Electronics	or equiv; DIP
K1, K2	2	Relay, dpdt, 12vdc coil	DS2Y-S-DC12V	Panasonic	DIP package
		Display Board			
B1, B2	2	Diode rectifier bridge	NTE5332	NTE Electronics	or equiv; DIP
reg 2, 3	2	5 vdc voltage regulator	LP2950-50LPRE3	Texas Instruments	to-93; from Mouser
	various	resistors, 1/4 w			current limit res; 150, 240, 330 ohm
	10	Panel mount LED	SSI-LXR1612xD	Lumex, Inc	x is color code, from Digikey

TBG Train Control System

REF	Qty	Description	Part # or Designation	Company	Notes
		Watchdog Timer			
	1	Picaxe 08M2 Proto Bd.	AXE021	Revolution Edu	from SparkFun Electronics
	1	micro controller	08M2+	Revolution Edu	from SparkFun Electronics
	4	resistor, 1k ohm, 1/4w			
	2	resistor. 330 ohm, 1/4w			
	2	LED, 5mm, red			
		Infrared START Switch			
	1	micro controller	08M2+	Revolution Edu	from SparkFun Electronics
IR LED	1	Infrared LED	TSAL6200	Vishay	from Mouser
IR Rec	1	Infrared receiver	TSSP4038SS1XB	Vishay	from Mouser
T1, T2	2	transistor, npn	2n4401		TO-93
	1	resistor, 33k ohm, 1/4w			
	2	resistor, 4.7k ohm, 1/4w			
	2	resistor, 240 ohm, 1/4w			
	1	resistor, 10k ohn, 1/4w			
	1	resistor, 150 ohm, 1/4w			
	1	diode	1n4001		in "SW-" output wire

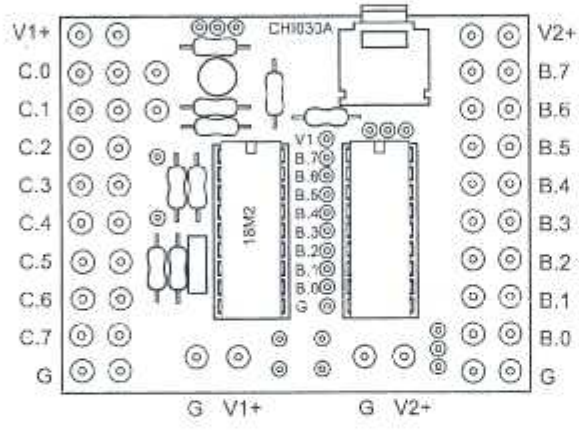
CHI030A PICAXE-18 Standard Project Board

Introduction

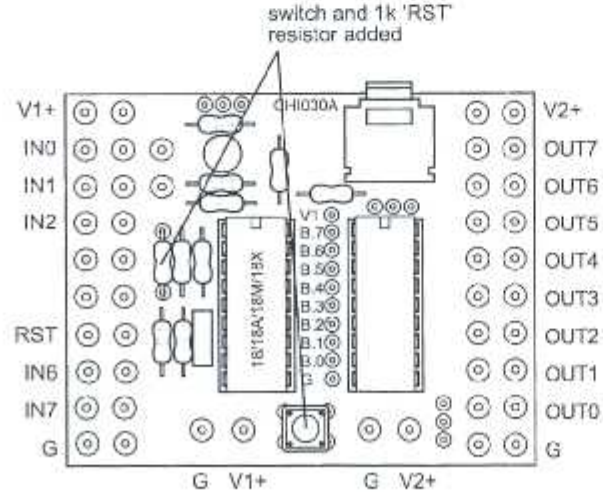
The CHI030A standard board uses a darlington driver IC to provide power to 8 digital (on/off) outputs (PICAXE pins B.0 to B.7). Each output is rated at 500mA. 6 digital (or 4 digital/2analogue) inputs are also available (PICAXE pins C.0 to C.7), all prefitted with a 10k pull down resistor for ease of use.

A high power board is also available (part CHI035A) separately. This uses 4 FETs to provide 4 high power digital outputs (rated at 1.5A each), and the option of a L293D motor driver IC to provide 2 reversible motor outputs, rated at 1A each.

Both boards are supplied ready for immediate use with the PICAXE-18M2 chip. The inputs (portC) are on the left and buffered outputs (portB) are on the right. The direct (non-buffered) portB PICAXE outputs are also available in the centre of the board for connection to logic level devices (e.g. an AXE033 Serial LCD).

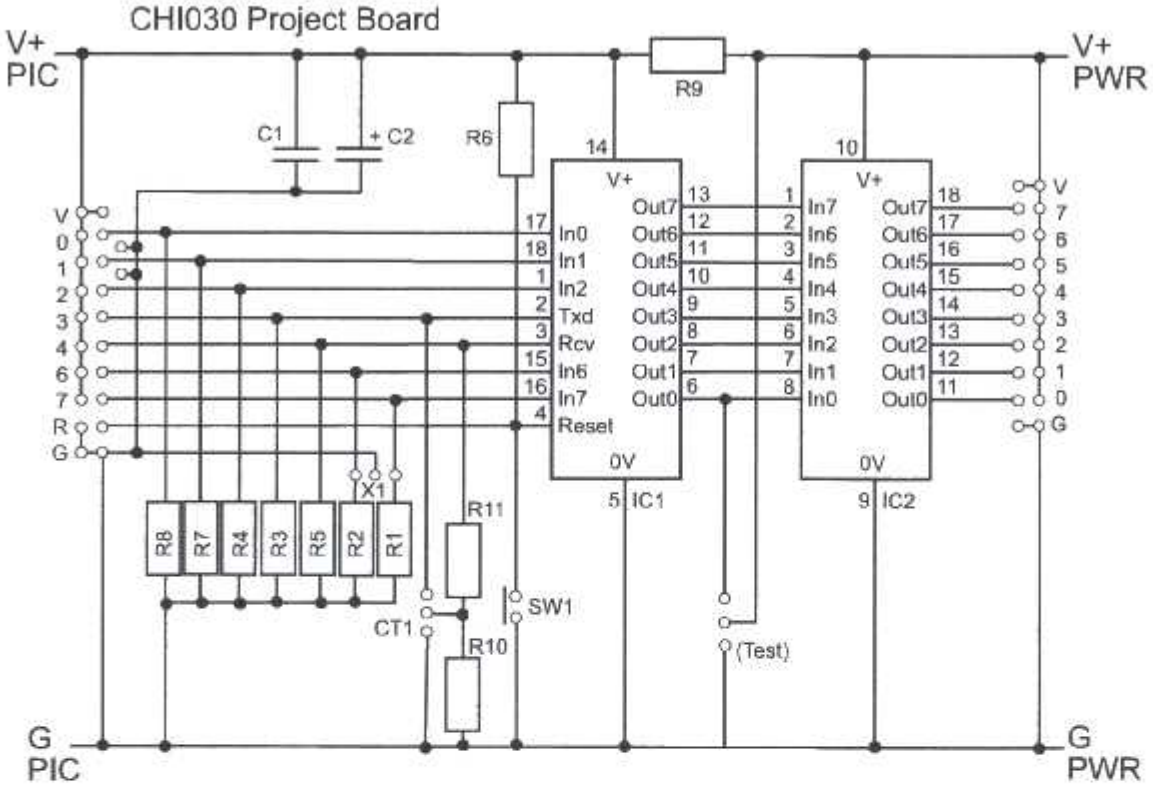


To use the board with an older (now discontinued) 18/18A/18M/18X PICAXE part an extra 1k resistor *MUST* be soldered to the board in the 'RST' resistor position. If desired an optional reset switch (part SEN030) may also be fitted in position 'S1'. Note that the current release PICAXE-18M2 does not have a reset pin, so does not require the RST resistor or the reset switch to be fitted.



For the full datasheet for this product please see www.rev-ed.co.uk/docs/chi030a.pdf

CHI030 Circuit Diagram



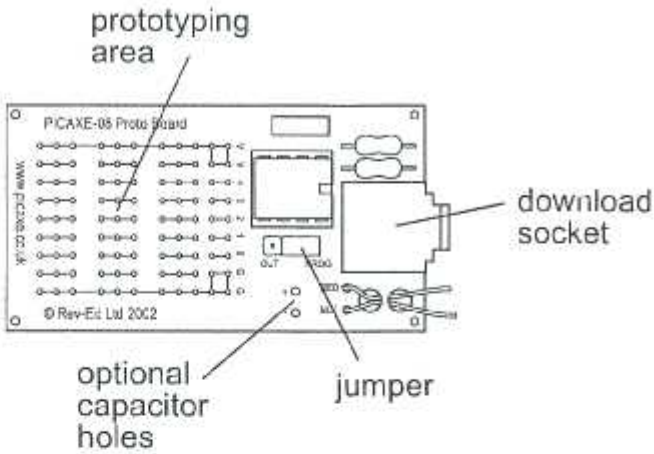
CHI030 / CHI035 Parts List

R1-5, 7,8,10	10k resistor
R6	4k7 resistor
R9	100R resistor
R11	22k resistor
CT1	3.5mm stereo PICAXE download socket
SW1	minature reset switch
C1	100nF polyester
C2	100uF 16V electrolytic
IC1	PIC 18M2
IC2	ULN2803A (CHI030 only)
Additional CHI035 parts	
IC2	L293D (optional)
D1-4	1N4001 diode
Q1-4	IRF520 FET
C3-4	220nF polyester

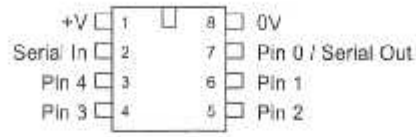
PICAXE-08 PROTO BOARD KIT

AXE021 PICAXE-08 Proto Board Kit

Watchdog Timer is built on this proto board

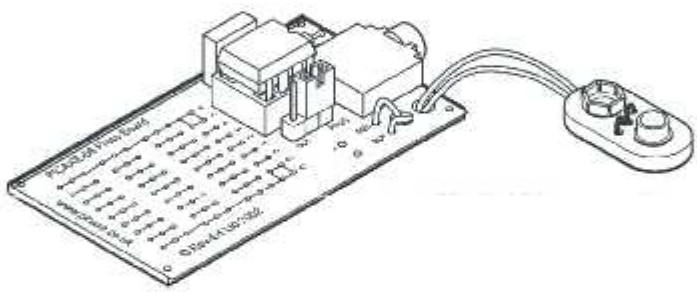


PICAXE-08



Contents:

- PCB Proto board PCB
- R1 10k resistor (brown black orange gold)
- R2 22k resistor (red red orange gold)
- C1 100nF polyester capacitor
- H1 3 pin header and jumper link
- CT1 stereo download socket
- BC Battery Clip
- IC1 8 pin IC socket



Description:

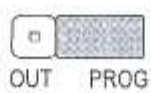
The PICAXE-08 proto board provides a rapid development system for the PICAXE-08 microcontroller system. It provides the basic download circuit beside a small proto typing area for connection of input / output circuits to the PICAXE-08 pins.

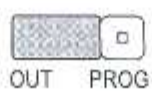
Instructions:

1. Solder the components in place. Note the battery clip can be threaded through the board prior to soldering to generate a stronger joint.
2. Insert a PICAXE-08 or 08M microcontroller (purchased separately). If desired an electrolytic capacitor (e.g. 100uF) may be soldered beside the battery clip for voltage smoothing on noisy circuits. ONLY USE A 4.5V or 5V battery pack, not a 9V PP3 battery, as the power supply.
3. Use the prototyping area to develop your test circuit. Note the pads are joined in sets of pads (and power rails) as marked in ink on the top of the board.
4. Use the Programming Editor software to develop a control program, and then download the program to the board by connecting the PICAXE USB download cable (part AXE027) or serial cable (part AXE026).

Pin0:

Note that pin0 is used as both output 0 and the serial output during a download. Ensure the jumper is moved to the correct position as appropriate for each use.





TYPES

Contact arrangement	Nominal coil voltage	High sensitivity type		Standard type	
		Single side stable type	2 coil latching type	Single side stable type	2 coil latching type
		Part No.	Part No.	Part No.	Part No.
1 Form C	1.5 V DC	DS1E-S-DC1.5V	DS1E-SL2-DC1.5V	DS1E-M-DC1.5V	DS1E-ML2-DC1.5V
	3 V DC	DS1E-S-DC3V	DS1E-SL2-DC3V	DS1E-M-DC3V	DS1E-ML2-DC3V
	5 V DC	DS1E-S-DC5V	DS1E-SL2-DC5V	DS1E-M-DC5V	DS1E-ML2-DC5V
	6 V DC	DS1E-S-DC6V	DS1E-SL2-DC6V	DS1E-M-DC6V	DS1E-ML2-DC6V
	9 V DC	DS1E-S-DC9V	DS1E-SL2-DC9V	DS1E-M-DC9V	DS1E-ML2-DC9V
	12 V DC	DS1E-S-DC12V	DS1E-SL2-DC12V	DS1E-M-DC12V	DS1E-ML2-DC12V
	24 V DC	DS1E-S-DC24V	DS1E-SL2-DC24V	DS1E-M-DC24V	DS1E-ML2-DC24V
	48 V DC	DS1E-S-DC48V	DS1E-SL2-DC48V	DS1E-M-DC48V	DS1E-ML2-DC48V
2 Form C	3 V DC	DS2E-S-DC3V	DS2E-SL2-DC3V	—	—
	5 V DC	DS2E-S-DC5V	DS2E-SL2-DC5V	—	—
	6 V DC	DS2E-S-DC6V	DS2E-SL2-DC6V	—	—
	9 V DC	DS2E-S-DC9V	DS2E-SL2-DC9V	—	—
	12 V DC	DS2E-S-DC12V	DS2E-SL2-DC12V	—	—
	24 V DC	DS2E-S-DC24V	DS2E-SL2-DC24V	—	—
	48 V DC	DS2E-S-DC48V	DS2E-SL2-DC48V	—	—

Standard packing: Carton: 50 pcs.; Case: 500 pcs.

RATING

1.Coil data

- Operating characteristics such as 'Operate voltage' and 'Release voltage' are influenced by mounting conditions, ambient temperature, etc.
  Therefore, please use the relay within ± 5% of rated coil voltage.
- 'Initial' means the condition of products at the time of delivery.

1) Single side stable type

Type	Nominal coil voltage	Pick-up voltage (at 20°C 68°F)	Drop-out voltage (at 20°C 68°F)	Nominal operating current [±10%] (at 20°C 68°F)	Coil resistance[±10%] (at 20°C 68°F)	Nominal operating power	Max. applied voltage (at 50°C 122°F)
Standard (M) type	1.5 V DC	70%V or less of nominal voltage (Initial)	10%V or more of nominal voltage (Initial)	266.7 mA	5.63 Ω	400 mW	1 Form C: 120%V of nominal voltage
	3 V DC			133.3 mA	22.5 Ω		
	5 V DC			80.0 mA	62.5 Ω		
	6 V DC			66.7 mA	90 Ω		
	9 V DC			44.4 mA	203 Ω		
	12 V DC			33.3 mA	360 Ω		
	24 V DC			16.7 mA	1,440 Ω		
	48 V DC			8.3 mA	5,760 Ω		
High sensitivity (S) type	1.5 V DC	1 Form C: 80%V or less of nominal voltage 2 Form C: 70%V or less of nominal voltage (Initial)	10%V or more of nominal voltage (Initial)	133.3 mA	11.3 Ω	200 mW	1 Form C: 160%V of nominal voltage 2 Form C: 220%V of nominal voltage
	3 V DC			66.7 mA	45 Ω		
	5 V DC			40.0 mA	125 Ω		
	6 V DC			33.3 mA	180 Ω		
	9 V DC			22.2 mA	405 Ω		
	12 V DC			16.7 mA	720 Ω		
	24 V DC			8.3 mA	2,880 Ω		
	48 V DC			4.2 mA	11,520 Ω		

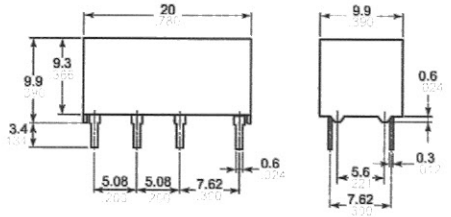
2) 2 coil latching type

Type	Nominal coil voltage	Set voltage (at 20°C 68°F)	Reset voltage (at 20°C 68°F)	Nominal operating current [±10%] (at 20°C 68°F)		Coil resistance [±10%] (at 20°C 68°F)		Nominal operating power		Max. applied voltage (at 50°C 122°F)
				Set coil	Reset coil	Set coil	Reset coil	Set coil	Reset coil	
Standard (M) type	1.5 V DC	70%V or less of nominal voltage (Initial)	70%V or less of nominal voltage (Initial)	240 mA	240 mA	6.25 Ω	6.25 Ω	360 mW	360 mW	1 Form C: 120%V of nominal voltage
	3 V DC			120 mA	120 mA	25 Ω	25 Ω			
	5 V DC			72 mA	72 mA	69.4 Ω	69.4 Ω			
	6 V DC			60 mA	60 mA	100 Ω	100 Ω			
	9 V DC			40 mA	40 mA	225 Ω	225 Ω			
	12 V DC			30 mA	30 mA	400 Ω	400 Ω			
	24 V DC			15 mA	15 mA	1,600 Ω	1,600 Ω			
	48 V DC			7.5 mA	7.5 mA	6,400 Ω	6,400 Ω			
High sensitivity (S) type	1.5 V DC	1 Form C: 80%V or less of nominal voltage 2 Form C: 70%V or less of nominal voltage (Initial)	1 Form C: 80%V or less of nominal voltage 2 Form C: 70%V or less of nominal voltage (Initial)	120 mA	120 mA	12.5 Ω	12.5 Ω	180 mW	180 mW	1 Form C: 160%V of nominal voltage 2 Form C: 220%V of nominal voltage
	3 V DC			60 mA	60 mA	50 Ω	50 Ω			
	5 V DC			36 mA	36 mA	139 Ω	139 Ω			
	6 V DC			30 mA	30 mA	200 Ω	200 Ω			
	9 V DC			20 mA	20 mA	450 Ω	450 Ω			
	12 V DC			15 mA	15 mA	800 Ω	800 Ω			
	24 V DC			7.5 mA	7.5 mA	3,200 Ω	3,200 Ω			
	48 V DC			3.75 mA	3.75 mA	12,800 Ω	12,800 Ω			

DS (2 Form C)
Single side stable

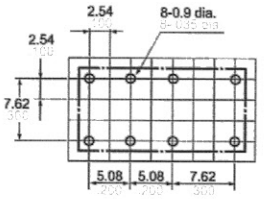
CAD Data

External dimensions

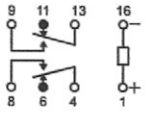


General tolerance: ±0.3 ±.012

PC board pattern (Bottom view)



Schematic (Bottom view)



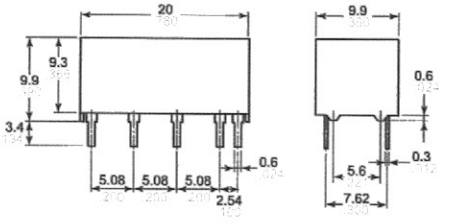
(Deenergized condition)

Tolerance: ±0.1 ±.004

DS (2 Form C)
2 coil latching

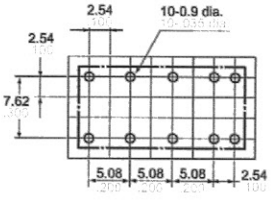
CAD Data

External dimensions

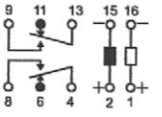


General tolerance: ±0.3 ±.012

PC board pattern (Bottom view)



Schematic (Bottom view)



(Reset condition)

Tolerance: ±0.1 ±.004

NOTES

1. Coil connection
When connecting coils, refer to the wiring diagram to prevent mis-operation or malfunction.