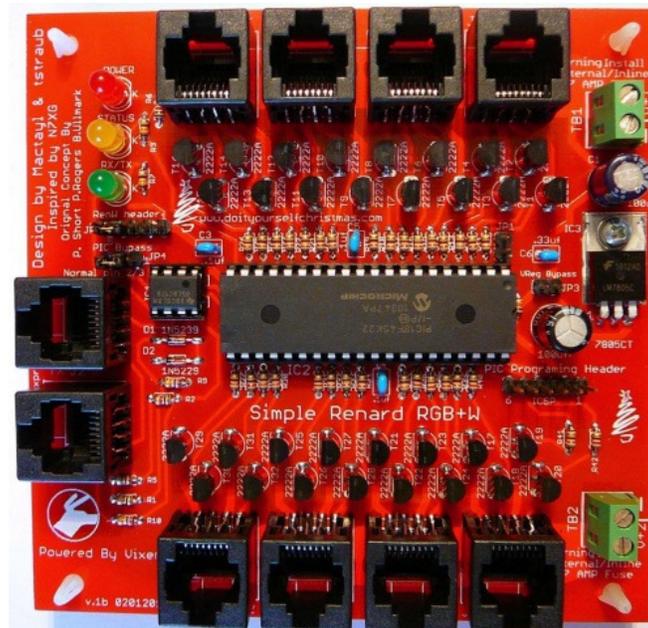




## Simple Renard RGB+W Controller



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Document revision 2.0

Renard-Plus, Salem, Oregon 97302  
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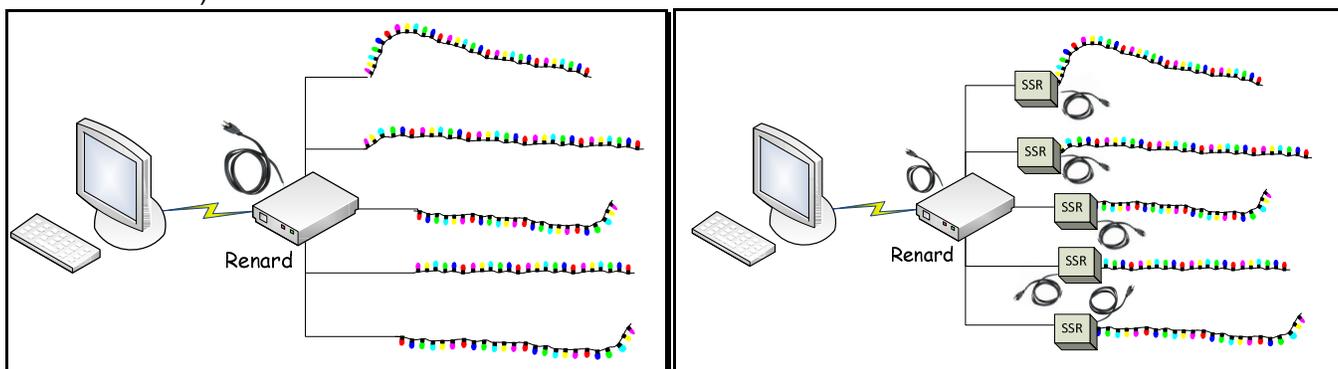
# 1. Overview

## 1.1 Introduction to Renard

Renard is the name of a “do-it-yourself” (DIY), computer-controlled, PIC-based dimmer light control concept. It also refers to a family of dimming controllers that have been designed and built based on this concept.

The Renard design concept was originally described by Phil Short in the [Simple PIC-Based 8-Port Dimmer](http://computerchristmas.com) 'How-To' on the <http://computerchristmas.com> website. Since then there have been many enhancements and new designs based on this hardware. There have been many contributors to advancing Renard technology including M. Macmillan, D. Davis, P. Rogers, T. Straub, D. Haberle, A. Williams and others

Renard controllers typically rely on a separate computer running a light sequencing program to send it real-time sequences of controller commands to sequence the lights. The computer communicates with the Renard via RS232, RS485, or wireless (depending on the design) and the Renard controls the lights either through built-in power control (power is output directly to the lights), or via separate “SSRs” (solid state relays supply the power when commanded by the controller).



EXAMPLE RENARD CONFIGURATIONS

Output of the Renard can be control signals (to an SSR), direct AC line voltage (110, 100/220, or 220), DC voltage or a combination of these depending on the design.

Renard is a DIY hobbyist effort and there is a vast amount of products and related peripherals to select from including the Renard Plus Strip Controller. To obtain a specific design, there might be “buy a parts kit and/or blank PCB” offering at a site (such as from [www.renard-plus.com](http://www.renard-plus.com)), “etch it yourself” files for true DIY, or coop/group buys for kits and PCBs also in forums (like [DIYChristmas.org](http://DIYChristmas.org)).

## 1.2 Renard Plus Simple Renard RGB+W

This guide covers the Renard Plus Simple Renard RGB+W board. The board was designed in the Fall of 2011 by Mactayl and tstraub, inspired by n7xg, and based on original concepts by p. short, p.rogers and budude. The Simple Renard RGB+W is a low cost 32 channel DC controller designed to drive low current DC loads like RGB+W LED flood lights (such as [DIYC Flood](#), [Mighty Mini](#) or [Frank's Super Strip](#)). Unlike other DC designs like the [REN48LSD](#), the Simple Renard RGB+W makes use of a different PIC, the [PIC18F4520](#). This PIC allows 32 channels per PIC to be controlled compared to the usual 8 channels per PIC (16F688) used in

most Renard designs. This allows a smaller board and lower total cost. The design uses low cost NPN bipolar transistors to switch the loads to ground to power the outputs.

The board is capable of switching 5-24VDC at up to maximum of 500ma per channel for a very short period of time you should not exceed 400ma per channel for continuous use. The outputs use RJ45 jacks to provide easy access to the high channel count outputs. Power is supplied to the board thru two separate power inputs that allow a total of 7A to be supplied to each half of the board. The board requires either a 5vdc well regulated supply or a good 9-24vdc supply. An on board voltage regulator provides the necessary power for the PIC and transistors on the pcb.

For higher current DC loads it is also possible to connect [DC SSRs](#) to the output of the Simple Renard RGB+W to drive high current DC loads such as long LED RGB strips, motors or other inductive loads.

### 1.2.1 How does the Simple Renard RGB+W work?

The Simple Renard RGB+W uses a similar architecture for the logic portions of the board as the other Renard boards. Sequence information is passed from a PC running Vixen or other sequencing program via an RS-485 interface. The RS485 chip receives this information and turn into standard TTL logic levels that the PIC can understand. The PIC reads in the data and if it determines that the information corresponds to itself, it updates the dimming levels of all 32 channels. It removes this information from the stream and feeds the rest out to the RS485 chip which translates it to RS-485 levels for the next controller in the line. It is important to realize that the information is removed from the stream and that the resultant leftover stream will have all of the data offset by the 32 channels of information used by the Simple Renard RGB+W. For example, if you have two Simple Renard RGB+W, on Vixen you would configure a single Renard plug-in with 64 channels. The first Simple Renard RGB+W consumes the first 32 channels of information leaving only 32 channels on its outputs. The second Renard RGB+W will see this incoming data as controller #1 again and assume the data is for it. This is very much different than standard hard/soft-coded DMX or LOR devices that use a set address and still pass on the entire stream to the next controller on the line.

The PIC in the Simple Renard RGB+W uses the internal PIC oscillator.

So - now that the PIC has the updated dimming levels for all of its channels, it enables each of its outputs using PWM or Pulse Width Modulation. It is important to grasp that the voltage levels are not controlled - it is the amount of time on and off that is varied within a small cycle of time for each update. It seems logical that to dim things you would just change the voltage from 12v to 9v for example. Instead, the voltage is on at the full 12v for x amount of time and then it is off (0v) for the y amount of time - it is not something in-between. The cycle time is controlled by the PIC in the case of the Renard RGB+W. AC dimming Renard boards (such as the RP16 and TP8 Flex as well as others) use a Zero-Cross (ZC) signal which is created by an opto-isolator attached to the AC line (either directly to the mains or via a transformer and in both cases through some resistors to limit the current to the opto). Since the Renard RGB+W does not have any AC supplied to it, the PIC basically makes up it's own timing but it closely resembles what is seen with normal ZC usage.

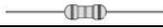
The Simple Renard RGB+W uses sourced outputs and not sinked outputs like the some other Renard controllers. Why is this? Because the PIC needs to turn on a transistor and to do this, it supplies 5v on it's output which turns on the transistor (via a resistor to limit the current) which

allows current to flow from the collector to the emitter of the transistor. The emitter is directly connected to ground so basically, the transistor sinks the current from the LEDs (or whatever you have attached to the output) to ground. The positive voltage from the DC power supply connects directly to the device you have attached and this completes the circuit.

### 1.2.2 DC power requirements

The Simple Renard RGB+W board requires either a 5vdc well regulated DC power supply or 9-24vdc supply either which are capable of powering the board AND the RGB+W floods (or other DC devices). The logic portions of the board requires a clean/regulated +5vdc supply. This can be supplied in two ways on the Simple Renard RGB+W. If you use a well regulated +5vdc power supply on TB1, you can leave off the voltage regulator / capacitor and install a jumper across the JP3 header. This will feed the power from the TB1 (V+1) jack directly to the logic components. Obviously care must be taken to ONLY use a 5vdc supply - if a 12v supply is connected in this configuration, you will “let out the magic smoke” and likely lose your PIC and RS485 chips in one shot. If you are planning to use a 9-24vdc supply then you must install the regulator / caps and leave JP3 without a jumper. This allows the power input on the TB1 (V+1) connector to be converted down to +5vdc to run the board logic including the PIC processor. It is important to realize that the 5v created is only used by the board and it is NOT sent out to the outputs of the Simple Renard RGB+W. The outputs always follow whatever you place on TB1 (V+1) and TB2 (V+2). The two connectors are separated so it is possible to run different voltages on TB1 (V+1) and TB2 (V2) (say 5v and 12v). Here again, extreme caution must be taken to ensure you do not mix up supplies or plug your device into the wrong outputs (like a 5v strip into a 12v output). In addition, you must ensure that the two power supplies will work harmoniously with a shared ground connection since the ground plane is shared between TB1 (V+1) and TB2 (V+2). A PC power supply is a good example of a power supply that will share ground between its +5 and +12 outputs. TB1 (V+1) powers Channels 1-16 (JP3-6). TB2 (V+2) powers channels 17-32 (JP7-10).

## 2. Simple Renard RGB+W Parts List

Picture	Designators	Description	Qty	Mouser P/N
	R1, R2, R6	1k ohm resistor 1/4 watt	3	291-1k-RC
	R3, R7	330 ohm resistor 1/4 watt	3	291-330-RC
	R4	10k ohm resistor 1/4 watt	1	291-10k-RC
	R5	120 ohm resistor 1/4 watt	1	291-120-RC
	R9, R10	27k ohm resistor 1/4 watt	2	291-27k-RC
	R11 – R42	820 ohm resistor 1/4 watt	32	291-820-RC
	D2	1N5229 (4.3v) zener diode	1	78-1N5229B
	D1	1N5239 (9.1v) zener diode	1	78-1N5239B
	C1 C2	100uf 35V Electrolytic Cap	2	647-UVZ1V101MED
	C6	.33uf cap	1	81-RDER71H334K1K103B
	C3, C4, C5	.1uf cap	3	81-RPEF51104Z2S2A03A
	TB1 TB2	Tyco Terminal Block vertical	2	571-7969492
	J1 - J10	Modular Jacks 8 PCB TOP ENTRY	10	571-5556416-1
		8 pin IC socket (optional)	1	517-4808-3004-CP
	IC1	IC & Component Sockets 40P	1	571-1-390261-9
		16 pin header cut to fit: ICSP, JP2 PIC Bypass, JP1 RenW, JP3 RS485 term.	1	571-16404526
		Shunts for XBheader and Bypass	3	737-MSG-G

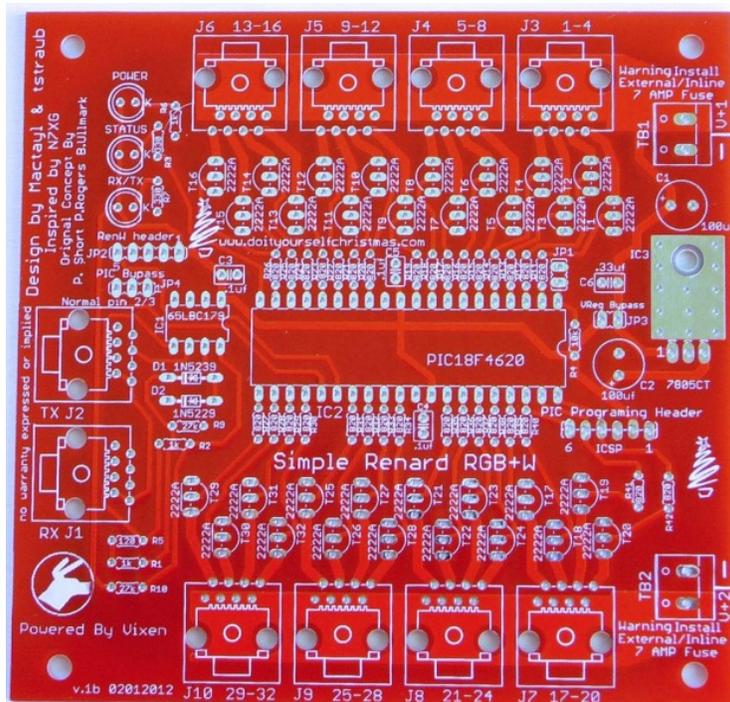
	IC4	LM7805CT voltage regulator	1	512-LM7805CT
	IC2	65LBC179	1	595-SN65LBC179P
	T1 – T32	PN2222AG transistor	32	863-PN2222AG
	IC1	PIC Microcontrollers (MCU) PIC18F4520 or 4620 and 4525	1	579-PIC18F4520-I/P
	Status	yellow 5 MM LED	1	78-TLHY5405
	Power	Red 5 MM LED	1	78-TLHR5401
	RX/TX	Green 5 MM LED	1	78-TLHG5401

## 3. Assembly

The Simple Renard RGB+W is a simple device to assemble and test. It is easiest if you build the units by inserting the various components from smallest to tallest.

### 3.1 First Things First

1. Begin by inspecting the PCBs to look for any defects such as cracks or breaks. The holes on the board should be open on both sides. Then inspect and sort out the various parts for the board.



2. Next inspect and sort out the various parts for the board. Make sure you understand which parts are which, and things like resistor codes and component orientation. A separate document on these concepts is available at [www.renard-plus.com/files/Tools and Parts ID Guide.pdf](http://www.renard-plus.com/files/Tools_and_Parts_ID_Guide.pdf) and on other resource sites like Wikipedia.
3. Follow the assembly guide as follows in the next section.

### **3.2 Install the components**

Generally, the following component assembly order is grouped from shortest to tallest parts to make assembly easier. Special instructions for component orientation should be listed if a component has any. Don't stress it- we try to make this as easy as possible!

#### **3.2.1 Install the resistors**

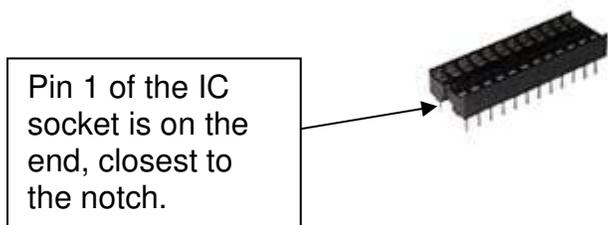
- Install the 1K (brown-black-red) ohm resistors at locations R1, R2, R6. The resistor are not polarized, so they can go either way.
- Install the 330 (orange-orange-brown) ohm resistors at locations R3, R7. The resistor are not polarized, so they can go either way.
- Install the 10K (brown-black-orange) ohm resistor at location R4. The resistor is not polarized, so it can go either way.
- Install the 120 ohm resistor at location R5. The resistor is not polarized, so it can go either way.
- Install the 27K (brown-red-brown) ohm resistors at locations R9,R10. The resistor are not polarized, so they can go either way.
- Install the 820 (grey-red-brown) ohm resistors at location R11 – R42. The resistor are not polarized, so they can go either way.

#### **3.2.2 Install the diodes**

- Install the 1N5239 diode at location D1. The diode is polarized and it can only go one way. The end with the band (cathode) goes towards the left side of the board.
- Install the 1N5229 diode at location D2. The diode is polarized and it can only go one way. The end with the band (cathode) goes towards the left side of the board.

### 3.2.3 Install the IC sockets

Even though these parts are optional we strongly recommend that sockets be used on all of the IC's. Pin 1 of the IC aligns to the square solder pad on the PCB.



- Install the 8 pin socket at location IC1. The notch on the socket should face the right side of the board, matching the silkscreen image.
- Install the 40 pin socket at location IC2. The notch on the socket should face the right side of the board, matching the silkscreen image.

### 3.2.4 Install the capacitors

- Install the 100uf Electrolytic Capacitors at locations C1 and C2. The capacitor is polarized. Be sure that the (+) lead is installed in the hole marked with a "+" symbol. The (+) lead is usually longer than the (-) lead, and the (-) lead is identified by a black stripe on the capacitor.
- Install the 0.33uf Ceramic Capacitor at location C6. The capacitors are not polarized, so they can go either way.
- Install the 0.1uf Ceramic Capacitors at locations C3, C4, C5. The capacitors are not polarized, so they can go either way.

### 3.2.5 Install the light emitting diodes

LED's (light emitting diodes) must be installed according to the silk screen pattern on the board. In looking at an LED you will notice a flat spot on one side of the LED:

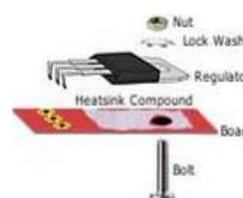


- Install the Red LED at the location marked Power. The LED is polarized. There is a flat side (cathode) that has a short lead and it faces towards the right side of the board.
- Install the Yellow LED at the location marked Status. The LED is polarized. There is a flat side (cathode) that has a short lead and it faces towards the right side of the board.
- Install the Green LED at the location marked RX/TX. The LED is polarized. There is a flat side (cathode) that has a short lead and it faces towards the right side of the board.

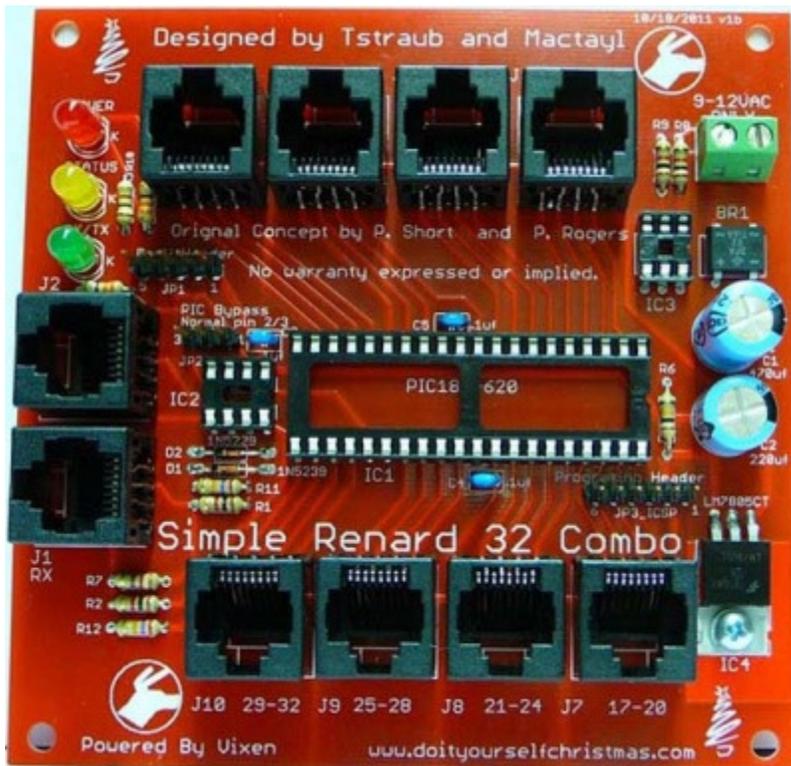
### 3.2.6 Install Misc. Parts (group 1)

You may have purchased either a single 16 pin header or headers cut accord to the board specifications

- Install the 5 pin header at location JP2 (RENV header). The short side of the header strip goes into the board.
- Install the 3 pin header at location JP4 (PIC bypass). The short side of the header strip goes into the board.
- Install the 2 pin header at location JP3 (vReg bypass). The short side of the header strip goes into the board.
- Install the 6 pin header at location ICSP (PIC programming header). The short side of the header strip goes into the board.
- Install the 5v linear regulator at location IC4. The voltage regulator is polarized and goes only one way. Gently bend the leads of the regulator at the location on the leads where it changes size down at a 90 degree angle towards the flat side of the regulator. Apply thermal grease to the flat heat sink side of the regulator and fasten it to the pcb using a #4 screw and nut. Despite the picture, it is better to have the screw come up through from the bottom of the board as show in the diagram).



- Install the RJ45 jacks at locations J1-10. Gently align the eight wires with the matching holes and snap the connector to the board. Solder the connector to the circuit board being careful to not short out the connectors.
- Install the 2 terminal strip1 at locations TB1 and TB2. The side where the wires enter under the screw should face the top of the board.



### 3.2.7 Install the jumper shunts:

- Install the shunts on the headers according to the [Header Settings](#) listed below.

### 3.3 Initial Testing / Final Assembly

The first thing you will want to do in any PCB construction project is to double check that you have all components installed and in the proper orientation. You will then want to inspect the board for any cold/bridged solder joints. Take your time with this step and go over each and every joint.

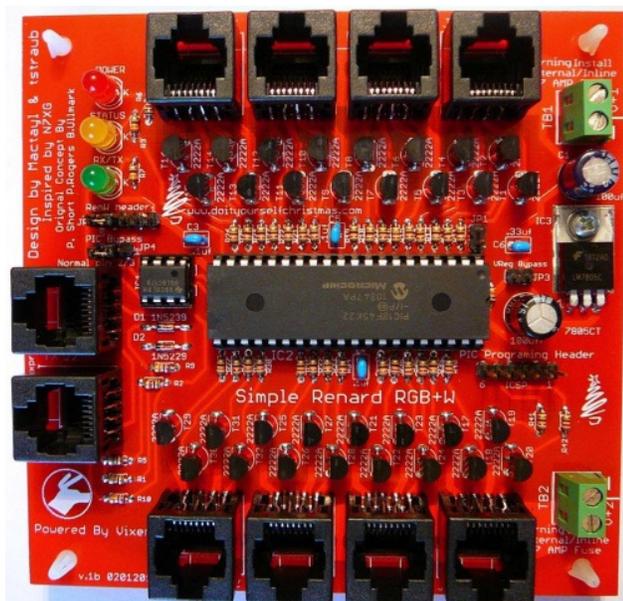
If you have any of the IC's (IC1, IC2) installed – remove them now.

Connect your power supply to the “TB1 (V+1)” - it supplies power to controller portion of the board as well as outputs 1-16. “TB2 (V+2)” is a separate input to drive outputs 17-32. Note that the ground is shared between the two inputs. If you are using a well regulated +5vdc power supply as your power input, the regulator circuit should not be installed. However, you must manually bypass this by placing a jumper on header JP3.

Turn on the supply and verify the power LED lights up. Verify you have 5v between pins 11 and 12 on the PIC socket as well as between pins 1 and 4 on the 485 chip socket. Install all of the IC's if this passes.

### 3.4 Install the ICs:

- Install the 32 PN2222AG transistors noting the silk screen pattern on the board must match the profile of the transistor.
- Install the PIC18F4520 in the 40 pin socket at location IC1. The IC is polarized. Gently install the IC so that the notch faces towards the right matching the socket and the silkscreen.
- Install the SN65LBC179P in the 8 pin socket at location IC2. The IC is polarized. Gently install the IC so that the notch faces towards the right matching the socket and the silkscreen.



**Congratulations! That completes the construction of the Simple Renard RGB+W !**

## 4. Final Steps

At this point you will have now completed the installation of all of the parts to the controller. Before you go ahead and insert the IC's into their sockets, we suggest you visually inspect the board and check to make sure there are no solder bridges between the solder pads, and that the solder joints are all a good quality. We would also recommend cleaning the copper side (bottom) of the PCB with a quality board cleaner to remove and resin residue after soldering.

### 4.1 Programming the PIC

*Note: The Renard Plus Simple Renard RGB+W **does not** use the default Renard firmware used on other Renard devices. Make sure you use the Renard Plus version of the code from the Renard-Plus.com website! There is firmware available for either Renard serial operation, or DMX.*

Programming the PIC can be done with the PIC chip plugged into a PIC programmer such as the PICStart from MicroChip or onboard using a programmer like a PicketIII or PicKit2. Programming PIC's using standard assembly is written up in our PIC Programming Manual available on [www.renard-plus.com](http://www.renard-plus.com).

### 4.2 Jumper Settings / Headers

#### 4.2.1 JP1 Pic Option

This option is currently unused and should be left without a jumper.

#### 4.2.2 JP2 "RENW" Wireless Header

This header can be used to connect a wireless module directly to the Renard Plus using a RF SnapIn, Xbee Snap-in board or indirectly using 3 wires to a board such as the REN-W. If you are not using wireless then you must jumper pins 4/5 using a shunt jumper. The following are the pinouts for the Xbee header:

##### Pin Layout

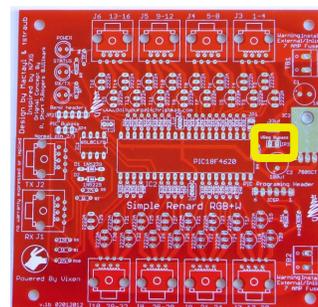
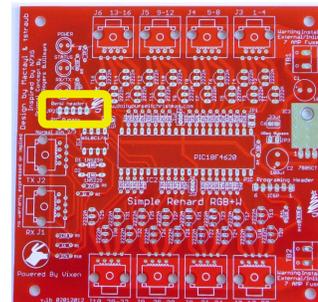
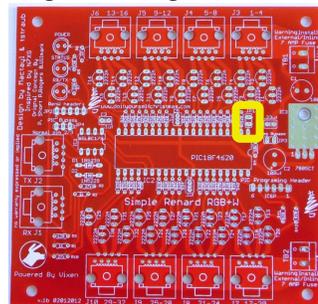
- 1 = +5VDC
- 2 = N/C
- 3 = GND
- 4 = RX from 485 chip
- 5 = RX in to PIC

*Option - Xbee using Snap-in Board*

Note: When assembling the DIGWDF Xbee Snap-In board (<http://diychristmas.org/store/>) install the female 5 pin header block on the bottom side of the board. Once assembled the Snap-in board can only be plugged in one direction.

#### 4.2.3 JP3 Voltage Regulator Bypass "Vreg Bypass"

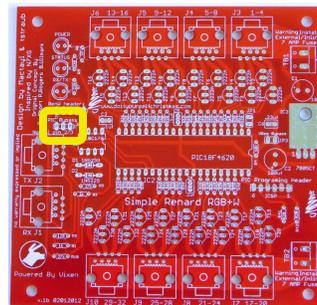
You can install a jumper to bypass the 5v voltage regulator **IF** the DC voltage you are inputting on TB1 is a well regulated 5V. If the DC voltage on TB1 is higher than 5V, then you should NOT put a jumper on this pin.



#### 4.2.4 JP4 PIC Bypass

If you are using Start Address Programming, you can use the PIC bypass to allow the data to flow thru the Simple Renard RGB+W without the usual Renard "address eating". If you use a jumper across pins 1/2 then the data stream that comes into the device goes out exactly as it came in with no addresses consumed by the Simple Renard RGB+W. The default position is a jumper across pins 2/3.

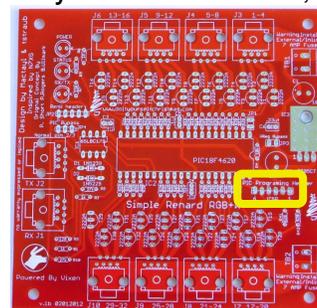
Pin	Description
1	Data In From RS485 IC
2	Data Out to RS485 IC
3	Data Out from PIC



#### 4.2.5 ICSP "Pic Programming Header"

This header allows the PIC to be programmed or reprogrammed while still plugged into the circuit board. To use the ICSP header plug your PICKIT programmer directly onto the header, making note to align pin 1 of the header with pin1 of the PICKIT.

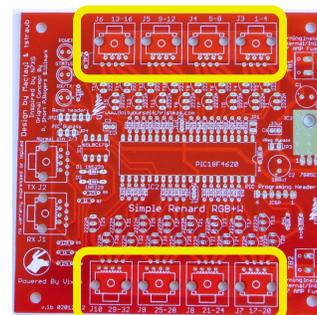
Pin	Description
1	MCLR
2	+5 volts
3	GND
4	PGD
5	PGC
6	PGM/RB5



#### 4.2.6 RGB+W Outputs (8)

Each RGB+W output of the Simple RGB+W board consists of an 8 pin RJ45 with the following pinouts:

Pin	Description
1,2,5,7	Normally the positive (+) DC as input from the DC supply or supplies on inputs TB1 or TB2 depending on which bank of outputs.
2	Outputs negative (-) for the FIRST (Red) Channel
4	Outputs negative (-) for the SECOND (Green) Channel
6	Outputs negative (-) for the THIRD (Blue) Channel
8	Outputs negative (-) for the FORTH (White) Channel

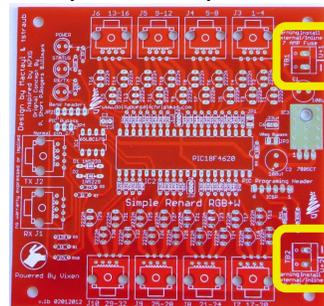


#### 4.2.7 DC Inputs (2)

Each bank of 4 RGB+W outputs has a DC voltage input connector. These are located at TB1 for J3, J4, J5 and J6 (channels 1-16), AND TB2 for J7, J8, J9, and J10 (channels 17-32). The polarity of the inputs is marked on the board. As shown, the TOP pin of TB1 is the positive (+) for the DC input, and the bottom pin is the negative (-). For TB2, it is the opposite, the TOP is the negative (-) for the DC input, and the bottom pin is the positive (+).

Pin	Description
<b>TB1 Upper</b>	DC positive (+) input.
<b>TB1 Lower</b>	DC negative (-) input
Pin	Description
<b>TB2 Upper</b>	DC negative (-) input
<b>TB2 Lower</b>	DC positive (+) input.

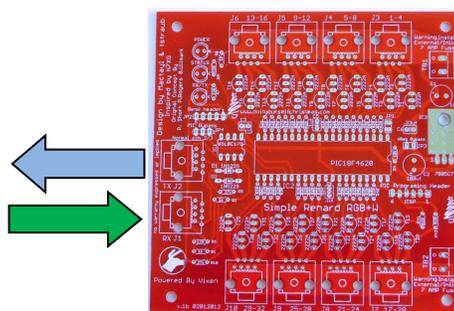
*Note: DC power should have a 7amp fuse before the board input!*



### 4.3 Connecting the Renard to your PC

This board contains 2 RJ45 connectors that are used to receive data and pass data to the next controller.

<b>J2 TX</b>	RS485 outgoing data to next controller
<b>J1 RX</b>	RS232/485 incoming data from either a serial port/ RS485 converter/DMX dongle, or another Renard board.



The data wiring of the Renard Plus TR8 FLEX is the same as other Renard boards including the Renard SS series so you can follow the same cabling requirements between other Renards and Renard Plus boards as follows.

For RS232, TR8 FLEX J1 RX pin 4 connects to the serial TX pin (pin 3 of a DE9 female) and J1 pins 5 and 2 and/or 1 connect to serial GND (pin 5 of a DE9 female). For RS485 operation, J1 pins 1 and 2 are GND, pin 4 is Data-, and pin 5 is Data+ on the RS485. RS485 connections vary.

There are many options to connect your computer to the Renard Plus TR8 FLEX. Pictured here is a Hexim HXSP-2018F USB to RS485 adapter. When selecting an adapter look for ones that have an easy to use screw terminal as shown.

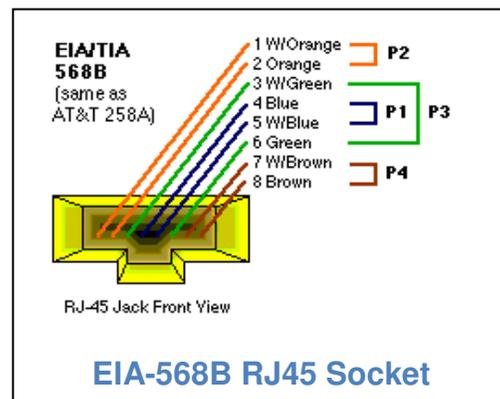


#### 4.3.1 RJ45 Wiring

A standard CAT5 (or better) RJ45 networking cable can be used to connect the Renard to to:

1. Your PC RS485 adapter
2. Another Renard for daisy chain operation or
3. SSRs if your board requires the use of SSRs (TR8 FLEX does not).

The cable must be a straight thru style and NOT a cross-over type cable. Just check and make sure that the pins on one end of the cable connect to the same pin on the other end of the cable (the wire colors in the connector are a way to tell- look for the same color pattern on both connectors). The diagram is an example of a data cable wired to the EIA-568B standard. There are eight pins, numbered from left to right, looking at the jack.



#### 4.3.2 DMX wiring

If you are using Renard Plus DMX firmware on your board, and will be using a “standard” DMX source, you may need to create a special interconnect cable, or adapter to get the DMX data into the correct pins on your Renard Plus. DMX adapters with an RJ45 output typically have data on pins 1(data+) & 2(data-) with GND on 7 or 8 of the connector, and Renards have data on pins 4 (data-) & 5(data+) with GND on pins 1 & 2. DMX configurations will vary so check carefully!

Signal	Renard RJ45	DMX RJ45
Data +	5	1
Data -	4	2
GND	1	8
GND	2	7

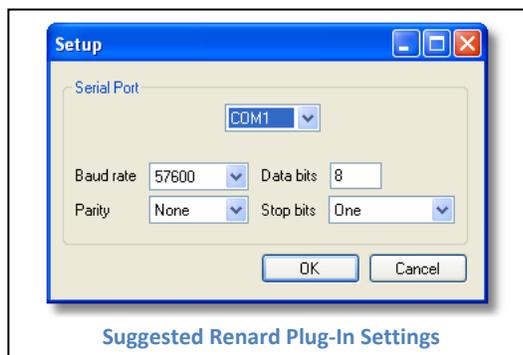
### 4.3.3 Computer Setup

If you are using the Vixen sequencing software to drive your Renard Plus with Renard firmware, it will require either one of the following plugins:

Renard Dimmer [Vixen 1.1.\*]

Renard Dimmer (modified) [Vixen 2.\*]

If you are using an Xbee, the baud rate must be 57600.



## 4.4 Final Testing

The Simple Renard RGB+W has 3 diagnostic LED status lights:

### 4.4.1 Diagnostic LED Status Lights

 RX	<b>RX/TX</b> – Active when sequence is running
 FE	<b>Status</b> – Will blink every few seconds to indicate the microprocessor is active
 PWR	<b>Power</b> - Will be on when power is applied

The design is fairly straight-forward and as long as you are sure of the voltage inputs and the PIC is flashed properly you should not have any issues if your soldering is good.

The data wiring of the Simple Renard RGB+W is the same as other Renard series boards so you can follow the cabling requirements for them.

### 4.4.2 Simple Sequence Testing

Connect the Simple Renard RGB+W to your PC using standard wiring practices. Develop a Vixen sequence to turn on/off each channel in groups of four using the appropriate Renard plug-in. Channels 1, 5, 9, etc should have the same programming but only have 1 channel in the group (1,2,3,4) on at a time. This helps ensure you have unique channel addressing from each RJ45 output.

With the sequence running, plug in a RGB+W device such as a [DIYC Flood](#) or [Super Strip strip](#) into each RJ45 and ensure each color turns on in order. Once that is complete you change the on/off to ramp up/downs to verify dimming operation. Finally, you can perform a full load test with 8 devices installed.

The Simple Renard RGB+W can be used to drive other devices as well of course. The [Mighty Mini](#) floods can be wired using normal RGBW wiring since the MM end of the cable goes into terminal blocks versus an RJ45 jack. Another popular flood is the [ChristmasOnManor Rainbow Flood](#). This is an RGB (no white) flood so it only uses 3 channels. The wiring uses pins 2, 4 and 8 to drive Red, Green and Blue. Note that pin 6 - or the 3rd channel is not used here. You have a few choices - in Vixen simply skip that channel, or if you really want to use that channel, you will need to do some creative cabling or not use the RJ45 jacks at all and wire the 3 channels directly to the board.

## 5. Parts Placement Diagram

