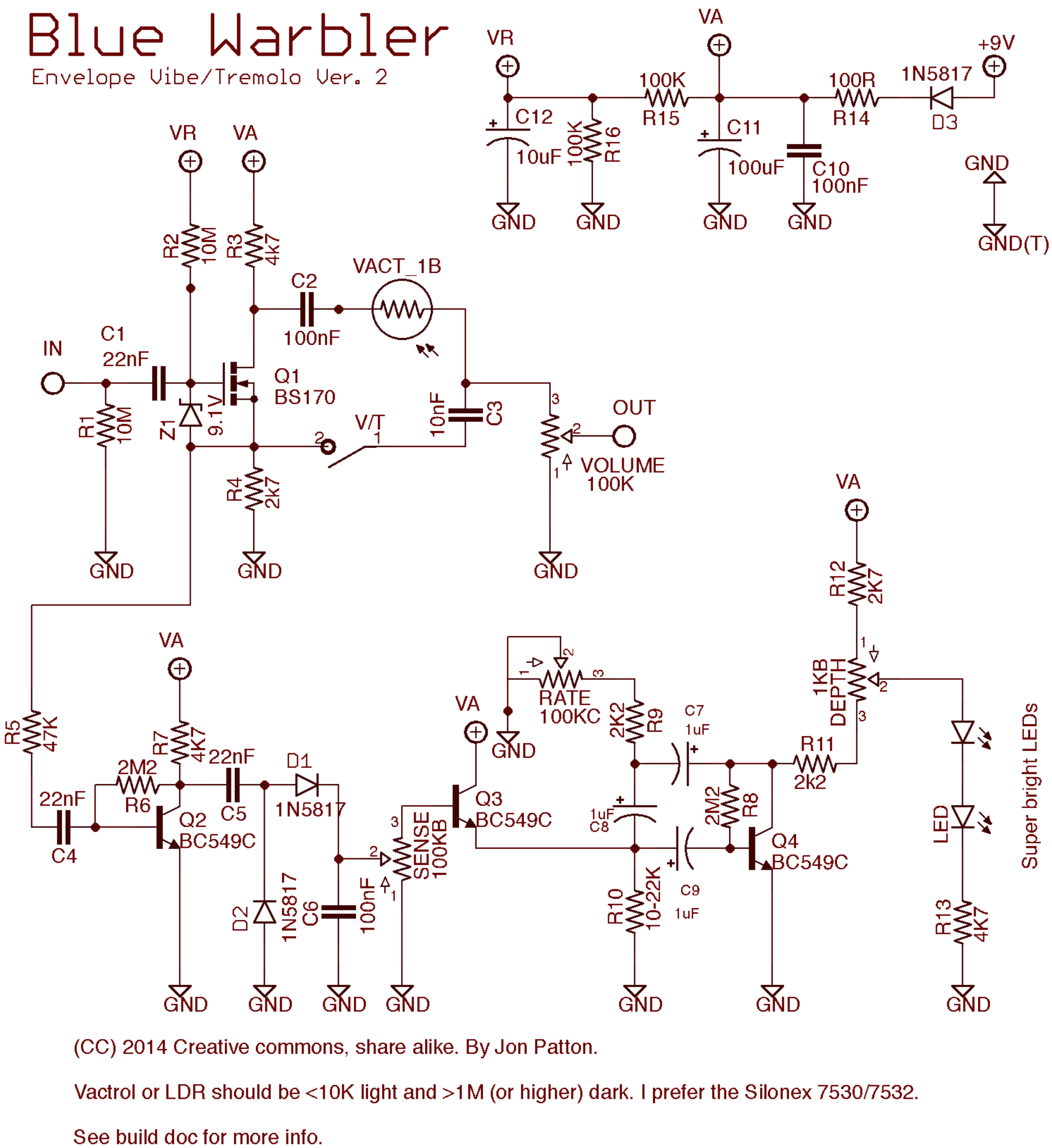
Blue Warbler Envelope Vibe and Tremolo

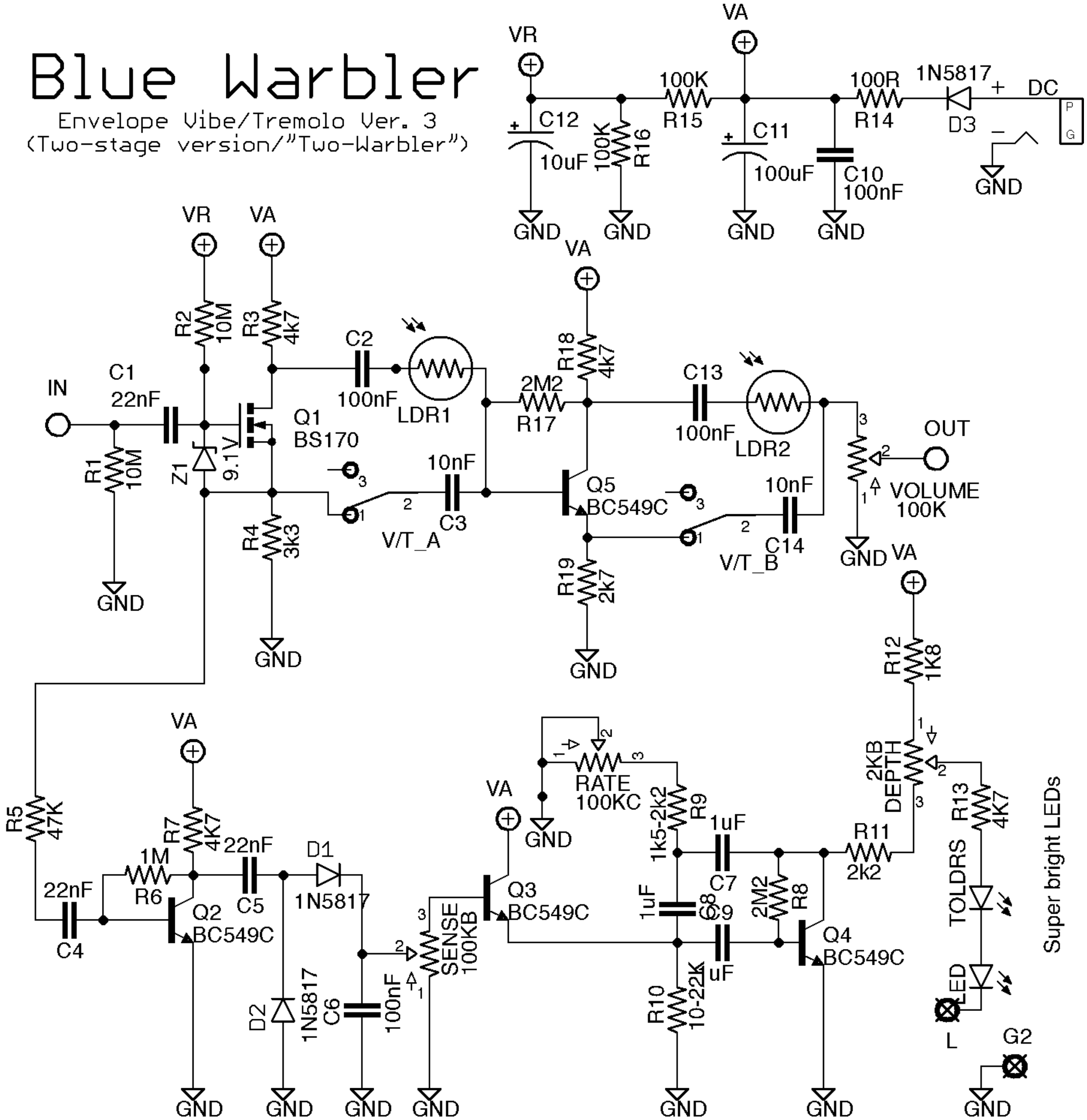
Version 2

The Blue Warbler is a vibe/tremolo project with envelope control over the LFO.

Schematic (single stage)



Schematic (multi-stage)



LDR should be <10K light and >1M (or higher) dark. I prefer the Silonex 7530/7532.
The two-stage version must use discrete photocells.

See build doc for more info.

Bill of Materials

Resistors		**R13**	4k7	**C6**	100nF	**Transistors**	
R1	10M	**R14**	100R	**C7**	1µF	**Q1**	BS170
R2	10M	**R15**	100K	**C8**	1µF	**Q2-Q5**	BC549C
R3	4k7	**R16**	100K	**C9**	1µF		
R4*	2k7/3k3	**R17***	2M2	**C10**	100nF	**LDR**	See notes
R5	47k	**R18***	4k7	**C11**	100µF	**Controls**	
R6	1M	**R19***	2k7	**C12**	10µF	**V/T switch**	SPST
R7	4k7	**Capacitors**		**C13***	100nF	**Sense**	100KB
R8	2M2	**C1**	22nF	**C14***	10nF	**Rate**	100KC
R9	1k5-2k2	**C2**	100nF			**Depth***	1KB/2KB
R10	10K-22k	**C3**	10nF	**Diodes**		**Volume**	100K trim
R11	2k2	**C4**	22nF	**D1-D3**	1N5817		
R12*	2k7/1k8	**C5**	22nF	**LEDs**	Blue		

*Only used in multi-stage version or value differs between versions. Second value is for the multi-stage.

Notes and Mods

This build document is for the perfboard build. Please refer to the JMK PCBs documentation (when it comes out) for the PCB project of the single-stage version. You can watch a demo of the prototype of version 2 here. The only difference between what is in the video and what is presented below is a slight change to the depth control to improve its range and feel.

Q1: You can also use a BJT for this transistor. It will have worse input impedance, but it's cheaper.
Q2-Q4: These can be any medium-gain transistor, but I prefer the 549C because it has tighter tolerances. You can use pretty much anything for Q3.
R9 and R10: These help set the speed range. You can reduce R9 slightly (try 1k5) to get slightly faster maximum speeds. You can also adjust R10 to get some faster or slower speeds. A larger value (try 22K) is slower; a smaller value (try 10K) is faster. If you go faster, consider lowering R11 (1k5). I prefer 1k5 for R9 and 15K for R10.
R4 and R19: You can adjust these to change the character of the vibe effect. See "How It Works."
LEDs: Stick with superbright LEDs (blue or white … but come on, it's called the *Blue* Warbler!) for both.
The L pad on the two-stage PCB is for the rate indicator. You can connect it to your footswitch where the LED would normally connect to use the rate indicator as your bypass indicator (so it will only blink

when the pedal is engaged) or you can connect it to the ground pad right next to it to have the rate indicator blink all the time. You MUST connect the L pad to something for the pedal to function.
LDR: See "How it Works" for a list of LDRs for this project. My preference is the Silonex 7532, which is currently available at Smallbear for $1.95 (or you can use their new "Hi-Dark" part).
R5: This helps set the overall threshold of the envelope section. If you use very low output pickups, you could use a smaller value (don't go below 10K). If you use high output pickups, you may want to increase it. 47K is a good compromise value and it worked with my strat, tele, and Sheraton.
Depth pot value: The value of the depth pot is larger in the two-stage version to handle the additional depth of the effect. (See "How It Works.") You can, of course, also use the 2K pot with the single-stage version, but I didn't find it necessary there and it's a harder-to-find value.

See "How It Works" below for more details and possible mods.

"Should I build the two-stage or single stage version?"

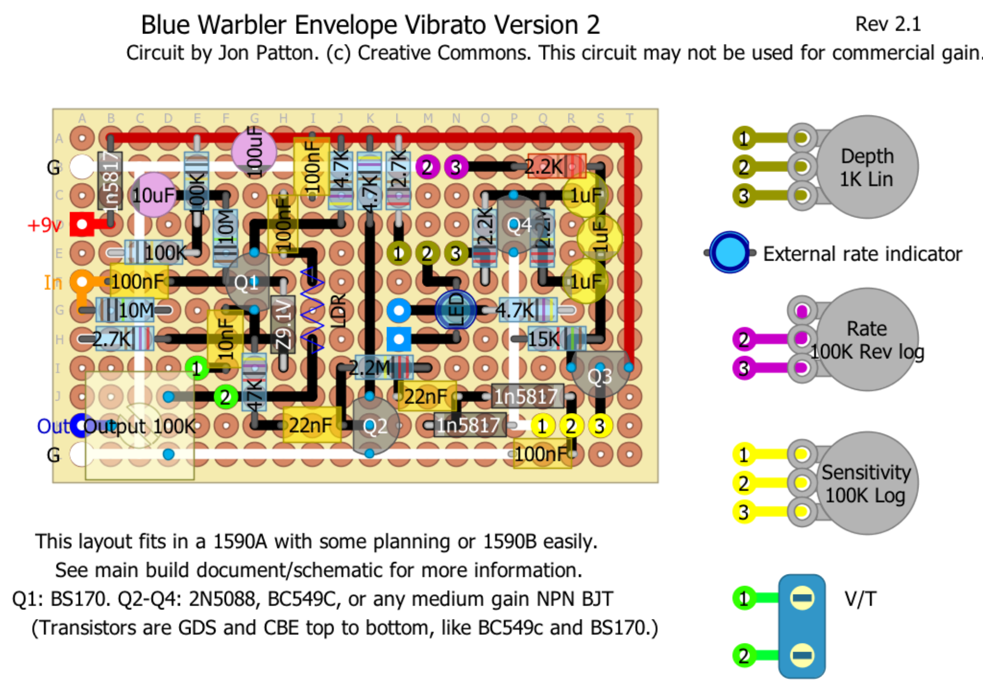
I developed the two-stage version primarily because it hedges bets against photocell variance for the vibe sound and also improves the tremolo mode, which were important to me in a product I sell periodically. If I were just building one for myself, I would be able to try multiple photocells (and indeed I did audition them in-circuit for the first couple V2s I made), but in the end it was simply easier for me to use and wire a a handful of extra parts and not have to worry about it. They sound slightly different. I do of course still think that the single-stage version is a worthwhile project, and it also fits in a 1590A without any 1/8W resistors.

If I just needed a mild effect, or wanted a 1590A, I would just build the single stage version, which I still think sounds very good as a sort of cross between vibe and tremolo with something extra. If I needed a more intense effect, or if I wanted something closer to a univibe sound, I would build the two-stage version.

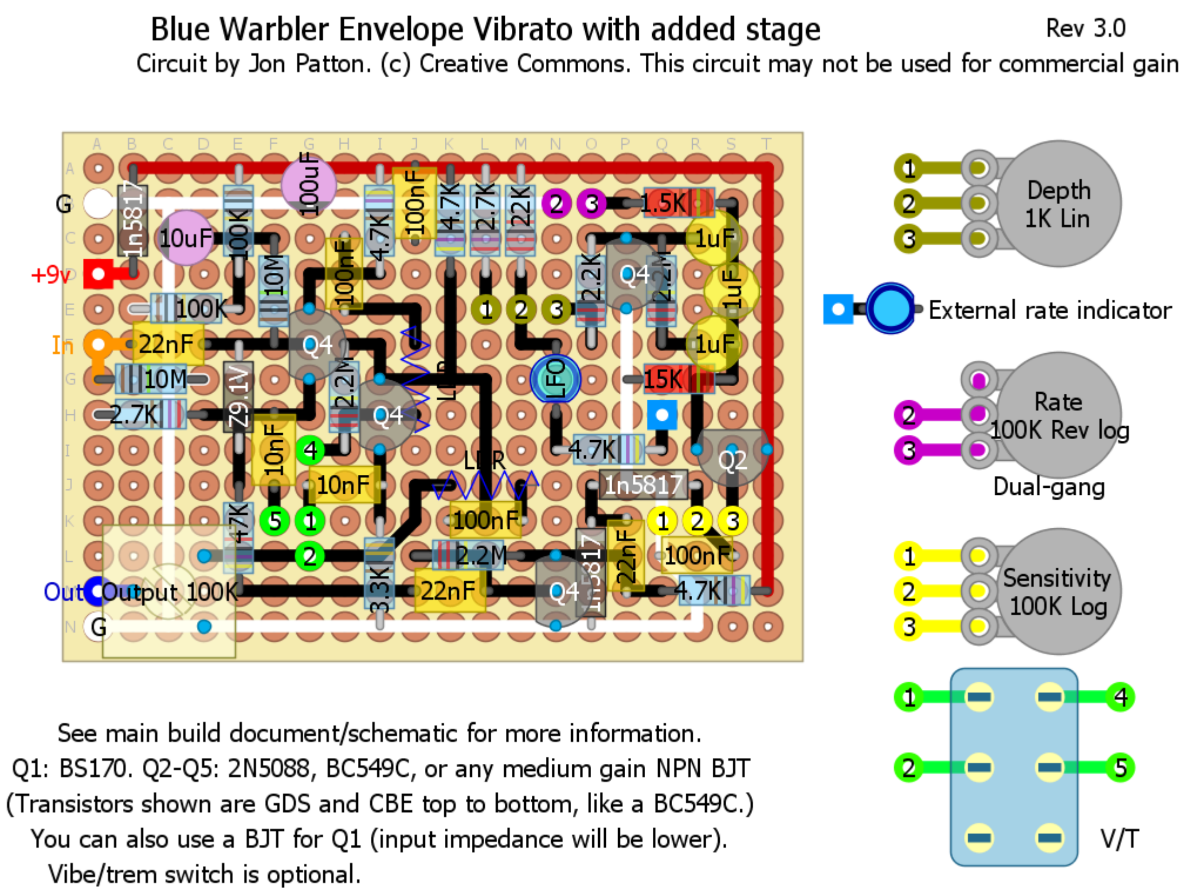
Perfboard Layouts

This is how I like to build them! (Note the 100nF on the far left of the PCB [the input cap] in the single-stage layout should be 22nF I will fix this as soon as I get the gumption ....)

Single-Stage Layout (appropriate for 1590As)



Two-Stage Layout (appropriate for 1590Bs)



Etch Masks

The etch layouts are identical to the perfboard layouts.

[Download the PDF (single-stage) to ensure proper page scaling](#).
[Download the PDF (two-stage) to ensure proper page scaling](#).

How It Works

Keep in mind that I'm just a guy with a breadboard, ears, and a dream, and not an electronics wiz. This is the best explanation I am able to give for the circuit.

Audio Path

The audio stage is a single MOSFET, with output from both the drain and source. It is based directly on the Tim Escobedo Wobbletron and the Magnavibe (which is just the Wobbletron with an LDR instead of a FET), as well as in part on Madbean's Quadrovibe, but with the change of using a MOSFET instead of a transistor.

I switched to a MOSFET to help with some input impedance issues, particularly when the effect followed a volume pedal or when the guitar's volume was set low; at one point in the sweep, a lot of noise would be present. (This was particularly a problem if the Blue Warbler followed an Ernie Ball Jr.) The input impedance is very high, about 5M (R1/R2). Input impedance wasn't the only reason, though; I chose a MOSFET over a FET because it also has greater predictability in terms of gain, lower output impedance, and higher headroom. A BJT can still be used without any ill effects, but it's nice to have the circuit set up to accommodate the better part.

As in all transistors, the source and drain outputs are out of phase with each other, which is how the Vibe effect is created. In vibe mode, it's a simple two-stage phaser. The source follower is a constant output with a higher cutoff frequency than the drain follower. The drain's amplitude is modulated, creating a single notch.

The two signals are mixed at lug 3 of the volume trim, which is just a standard voltage divider volume control. There's not a ton of extra volume here; most of the action is in the last ¼ turn. That's why it's inside instead of outside.

In the two-stage version, the entire process of Q1 is repeated by Q5: Signal enters at the base, is split into the collector and emitter signals, and then is mixed at the volume pot.

Some improvements from the original designs. If you take a look at the original Wobbletron, the output capacitors were in series. The emitter follower (source follower here) had a full-range output, but the collector (drain here) didn't. It actually had a bass cut. And then the variable resistance element was put in series with the full-range output. This meant that at low depth settings, the pedal was cutting a lot of bass! The Magnavibe made no effort to correct this oversight in the Wobbletron's design, and when I did the original Blue Warbler, it didn't occur to me to do anything about it. Simply rearranging things slightly -- moving the full-range output to the drain, and ditching the series capacitors -- works the same way but allows us to modulate the drain output instead. This became even more important with the addition of the tremolo mode, because now the output in both modes is nearly identical, whereas before the Vibe mode was louder.

Although the mechanism is simple, there are still some things that can be played around with in the audio path:

C3 (and C14). 10nF gives just enough cancellation to make the effect interesting. If you make C3 (and/or C14) larger, you will get more cancellation, though I found 22nF was about the largest you could get before it sounded weird. To duplicate the original Wobbletron, you would actually need to use a 47nF. Slightly smaller values will make for a more subtle effect, or simply change where on the guitar neck you get the most action.

*R4 (and R19).*The value of R4 was chosen in part to provide a bit of a boost to the drain output (which helps when you have an LDR in the way reducing its volume!), but it can also have an effect on the amount of phasing and pitch shifting you get. Using a 4k7 (same as R3) will provide the most pitch shifting at the cost of boosted output. I preferred the way a value approximately half of the drain resistor creates a more watery sound with just a bit of pitch shifting; it's somewhere between vibe, tremolo, and chorus. In the two-stage version, you can get an incremental gain increase by moving the 2k7 to Q5's emitter (for the slight boost) and using a slightly larger value for Q1 to enhance the phasing effect. I still didn't like the matched value for R4, but a slight increase to 3k3 worked very well.

LDR

The light dependent resistor (LDR) needs to have a pretty wide switching range to work with both the tremolo and vibe modes. First, you want a low light resistance for the vibe side. Below 10K is good; closer to 5K or even 1K is even better. Second, you want a high dark resistance to get the maximum depth and chop from the tremolo mode. 1M is acceptable; 10M or higher is better. The reason for this is that the tremolo is produced by the LDR forming a voltage divider with the resistance across the volume pot. Figuring out some ratios helps us here. A 1M dark resistance is a 10:1 change. That's just a little okay, so going higher will be beneficial.

The recommended LDR without any changes to the circuit are the Silonex 7530 or 7532 (essentially the same part) and Smallbear's CdS 9203 (or 9200).

Repositioning the LED slightly can also have an effect on the choppiness.

Here's what I tested:

Discrete

1. **Smallbear CdS 9200 and 9203 --** both very good for either mode. The 9203 sounds very slightly better than the 9200. The rise and fall times are very good. The best along with the 7532 of the discrete LDRs I tested, the only difference being that the 7532 was slightly smoother.

2. **Silonex 7532 or 7530** (they are the same part, with different packaging) -- As expected, works very well here in either mode. This is the photocell used in Madbean's Quadrovibe and in many univibe clones. These used to be the best possible choice for a vibe effect; unfortunately, as Smallbear posted recently, the current production ones are below spec on the depth of switching. A really good choice and the price is certainly really good.
3. Silonex 5542 -- decent for either mode, but not my favorite. They also cost more than the 7532.
4. Tayda's cheapies -- good/average for vibe, sometimes mild for tremolo. Often these will work fine, but they are a little inconsistent. If you can't get the recommended parts, these will at least work, but they are far from ideal. You might need to buy multiples and use a socket to pick the best one.

Photocouplers

None of the photocouplers I tested (listed below) work with the depth control shown in the schematic, but if you really want to use one, see the LFO section for one of the alternate depth controls. Considering these are significantly more expensive than an LED/LDR combo, I can't see them being worth the bother. The problem seems to be on the LED side more than the LDR side.

1. VTL5C1 - This is the original for the Blue Warbler. Unfortunately, the depth control as shown is meant to use a superbright LED, and consequently requires an adjustment to get any vibe effect at all. Even after making some adjustments to brighten the LED, it wasn't my favorite anymore for this effect. It still has an exceptionally good tremolo mode, but there are better tremolos to save it for (like the Cardinal).
2. VTL5C3 - Ditto.
3. MI1210CLE-R (Macron clone of the VTL5C1) - This will work okay with the alternate depth controls, though it will be harder to dial in.
4. MI1210CLF-R (VTL5C3 clone) - Ditto. There's no meaningful difference between this and the E.
5. Silonex NSL-32 - very shallow even on the vibe mode, and won't trem at all.
6. Silonex NSL-32SR2 - very good vibe with the alternate depth control (nice and smooth), but the tremolo mode doesn't work at all. Despite what the datasheet says, the rise/fall times in the whole NSL-32 series seems to be a little sluggish.
7. Silonex NSL-32SR3 - Ditto.
8. Clairex CLM6000 -- mine were "slightly out of spec" which is about the best you can get. The tremolo mode works well with the alternate depth control, but the vibe mode isn't very good. I wouldn't use these if I had other options, especially since they're $6 and rare.
9. H11F1 and other photoFETs or phototransistors -- none of these work; they all produce a lot of distortion in the audio path.

LFO

The LFO (Q4) is a basic phase shift oscillator (PSO)[1], modified to drive the LED for the LFO. This is fairly standard and is used in many effects, including the EA Tremolo, and it's nice because it's the absolute minimum parts required to get a good sine wave output.

I recommend using tantalum capacitors for C7--C9. They tend to work well in this sort of circuit and were recommended in the original EA Tremolo. Low ESR aluminum electrolytic capacitors will also work well.

Rate control. The rate control is simply a variable resistor on one leg of the PSO's ring of 1uF caps. I considered using the Univibe's rate control, which uses a dual gang and also varies R10 (the second gang would be set up the same way and replace R10), which gives the greatest possible speed range, but the dual gang pot was more expensive and complicated.

For the rate pot, the taper is reverse log to give a better spread of speed at the higher depth settings and prevent it from bunching up. You can also use a smaller value (50KC, or put a resistor in parallel) if your LFO latches. on the slowest speed setting, but I didn't have that problem in this version.

R10 has an effect on the speed range. Using a lower value (10K) will give you a faster range. Using a 22K will give you a slower range. 15K is a good compromise between them. The build in my demo uses a 22K, which ended up being a tiny bit slower than I'd ultimately prefer.

Depth control. In the Magnavibe and the original Blue Warbler, the LED for the photocell was connected in series with a collector resistor and the depth pot (which was just a variable resistor that added to the collector resistor). Here's what was less than ideal about that:

1. It changed the duty cycle. Lower depth settings would spend more time "off," and higher depth settings would spend more time "on."
2. Changing the depth would change the speed in some settings. Higher speed settings also kind of decreased the depth. (This went beyond the LDR's turn-on time affecting the depth.)
3. Similarly, it forced a limited speed range on the LFO. There's a risk of latching at certain depth and speed settings if you try to get a wider speed range.
4. It made the LEDs darker as the depth went down. As the LEDs went darker, the LDR's resistance rises and … hey, it loses more and more full-range signal as the depth goes down. Very annoying, and not just because I wanted to add a tremolo mode, which is almost useless with this setup on lower depth settings because it's mostly just silence. I don't that the original Wobbletron works this way, and I can't really think of another modulation pedal that does.

Thus began my quest to find an LED driver that would make the LEDs turn on fully when the depth was turned down. This wasn't an easy task, and I tried many things before arriving at the one shown. There are a few other ways of making it happen, but this was probably the least touchy, and it didn't involve more active elements. There are some other suggestions in the PSO thread I linked to earlier.

[1] You can read up on those here.

The depth control essentially divides between the steady DC source at pin 1 of the depth pot and the oscillating AC at the collector of Q2. As the depth is turned up, the current through the LEDs varies more. The range between "none" and "lots" was quite small, and after a lot (and I mean A LOT) of frustration, testing, poking, prodding, and eventually (shoulda done it earlier) actual *measuring*, I found that a 1K pot covered all the useable range with the right value resistors on either side (R11 and R12). There's a little bit of leeway here; you can lower R12 to, say, 1.8K to get a tiny bit more chop (only noticeable at the highest speed settings), but much lower and you won't be able to zero out the depth. R12 can be slightly bigger, up to about 3.3K, but again above that and you won't be able to zero out the depth. I settled on 1K8 and 2K7 because they were safe values and to simplify the bill of materials.

R13 limits current through the LEDs when the depth is at minimum. Fiddling with the value of this resistor can change how much chop you get to the LFO to some extent. A slightly higher value will let the LEDs get darker, providing a deeper cut.

Interestingly, there is also a slight lope and asymmetry to the oscillation in this setup, something that's also present in the univibe. That's pretty nice.

In the two-stage version, the depth control is very slightly altered to account for the more intense effect created by another stage. I decreased R12 slightly to lower the minimum, and then used a 2K linear pot. The range is roughly the same, with minimum having no (or almost no) effect and the top being rather intense. You can make these substitutions with the single-stage version, but they aren't as necessary and obviously require a rarer potentiometer value.

Alternate depth controls. I tested numerous other depth controls, including designs that used more active elements to isolate Q2 from the LEDs. For the unit in the demo, I used a 5KC for the depth control, without R11 or R12 to limit the range, and with a 22K from lug 2 of the depth to Va (which smoothed out the LED brightness). This control used two fewer resistors, but the feel is very bad. It does provide more control over the higher depth settings, but I didn't think it offered enough variance past half way to be as useful. The effect also didn't kick in until about 11:00. This meant the useable range was actually between 11:00 and 12:00. Or … about 1K, thus the 1K pot used in the final design. A third way to do the depth is to use a 50KC (again, omitting R11 and R12 and putting a 22K from lug 2 to Va), with a 5K6 in parallel with the pot (from Va to the Q2 collector). This forms the same 5K collector resistance as the previous method, but there is a larger range of resistance between the collector and the LEDs, so the vibe mode was a little easier to dial in compared with the 5K. The depth is the same in both at full. Both of these alternate depth controls have very slightly more depth at max than the depth control in the schematic, but in return you get a depth control that acts more like a switch, going from no effect to lots of effect in a very, very small range.

As far as adding active elements goes, I wasn't really getting better overall performance, and once you start adding more parts, you might as well use the LFO from the Tremulus Lune (and/or Shoot the Moon and/or Cardinal), or go big and use the LFO from Runoff Groove's Tri Vibe. The biggest reason for the phase shift oscillator is that it is so stingy on parts, cost, and PCB space. (And it's got an easy interaction with the envelope control.)

LEDs. The LEDs should be super bright, though you can use a red, yellow, orange, or green LED for the rate indicator if you really want to. But it's called the Blue Wabler. A blue LED just makes sense. The LED for the photocell will either be part of the photocoupler package, or you should use a superbright, and preferably a waterclear, for best results. Blue or white doesn't matter.

Envelope and Sense Control

R5 taps the signal at the Q1 source and feeds it through C4 to Q2. Q2 amplifies the signal pretty substantially, and it's then rectified by D1 and D2. It's peak-to-peak rectification. D1 and D2 are schottky diodes to take advantage of the very low Fv and lose as little voltage as possible. The signal is then fed into the base of Q3, which forms a voltage-controlled variable resistor between the power rail and R10. This is overall pretty basic, and it's also very similar to the rectifier in the Bearhug.

C6, with the Sense pot in parallel, controls the decay. The capacitor stores DC, and the resistance in parallel with it bleeds it off at a predictable speed. (Time in milliseconds = uF * KOhms.) At max, the decay is still very short, a mere 10mS, but we don't need a lot of decay because the LFO will take some time to spin back up depending on where the rate pot is set. All we're really interested in is giving the LFO a kick to stop it from oscillating for a moment.

The value of R5 is variable, but it can't be too low or it will create distortion. 47K was acceptable to me for both single coils and humbuckers, but particularly low or high output pickups could adjust this. I'd use 22K if you're an all-single-coils-all-the-time kind of person, or as high as 100K if you are all-in on humbuckers.

The sense control itself is a variable state filter, and it does multiple things at once.

- It controls the threshold by creating a voltage divider between ground and Q3 and a series resistance between D1 and Q3's base.
- It controls the frequency of the envelope by forming a variable low-pass filter with C5. Less bass means that the envelope isn't triggered as hard.
- It controls the decay by increasing the resistance in parallel with C6. The longer decay can help weaker pickups trigger the envelope easier.

From there, the rectified signal is applied to the base of Q3, which is referenced to +9V at its collector, and R10 (in the LFO) from its emitter. This stops the oscillation in the "up" swing, turning the LED on fully as if you had suddenly turned the depth control all the way down. The LFO will take a few cycles to recover. At faster speed settings, it recovers faster. At slower speed settings, it might take a while for it to come back in. The main purpose of the sense control is to set how easily this interaction occurs.

What else can we do here?

You can reverse the action of the envelope control (and cause the LED to go dark when you play) by referencing the collector to ground instead, but I found that this was much more extreme and harder to dial in. I'm not sure the exact reason the strength is so different, though.

One thing I miss from version 1 is that the sense control was capable of turning off the LFO, at which point it would only warble when you played. That can still be done by disconnecting R10 from ground with a switch. It's not as useful in tremolo mode, though.

Strictly speaking, there's no need to rectify the signal in the envelope section. You could just feed the decoupled output (which is AC) to the base of Q4 and be done with it. This seems to require a lot more signal to make it happen, though, so it would be a good idea to lower R5 to about 10K. And unlike the rectified signal, you can't change the decay in any way. It's instantaneous.

So that's the new version of the Blue Warbler. For what looks like a simple pedal, I sure talked a lot!

Credits: Thanks to Jacob for not accepting a less than perfect project and his extensive testing (not to mention putting up with dozens of e-mails); RG Keen for the Vibramatic idea in the first place; the folks who contributed to the PSO thread (especially PRR and RG); Tim Escobedo, wherever he is, for the Wobbletron; and Jack Orman (AMZ) for the MOSFET booster, the basics of which I used for the dry path.

Drilling Template

(Thanks to Josh at 1776 Effects)

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