

Transistor Matching for Woodworkers, Musicians, and Record Collectors

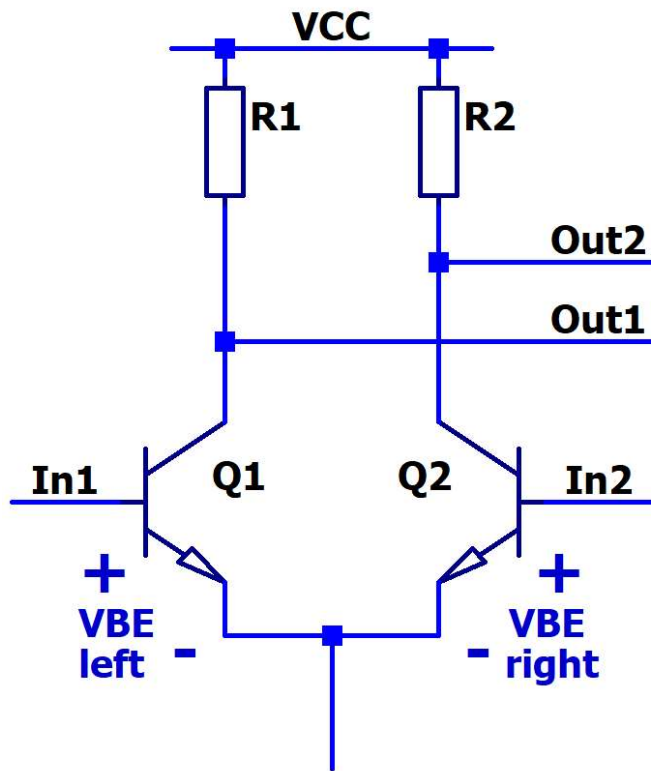
Burning Amp Festival 2024
Petaluma, CA

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The big idea

- Which Do-It-Yourselfers build their own electronic audio gear?
 - Hardcore electronics hobbyists (of course); AND ALSO
 - Speaker Builders
 - Record Collectors
 - Guitar players, Keyboardists, Musicians
- Let's make it easy for **anyone** to get better sound and better performance, by using matched transistors
- I present an easy, no-math, DIY transistor matching method. Maybe not "the best" or "the most elegant", but definitely simple. For **anyone**. Especially: for non-engineers
- We will match the "VBE" of low power bipolar transistors

What's VBE? Why does it matter?



- VBE = Base to Emitter voltage of a bipolar transistor
- At the front end of ~most~ amp ckts, is a Differential amplifier as shown. It requires two identical transistors for proper operation
- In the real world, they're not identical; they're *mismatched*
- So the diff-amp doesn't work as intended; it is a flawed, imperfect amplifier

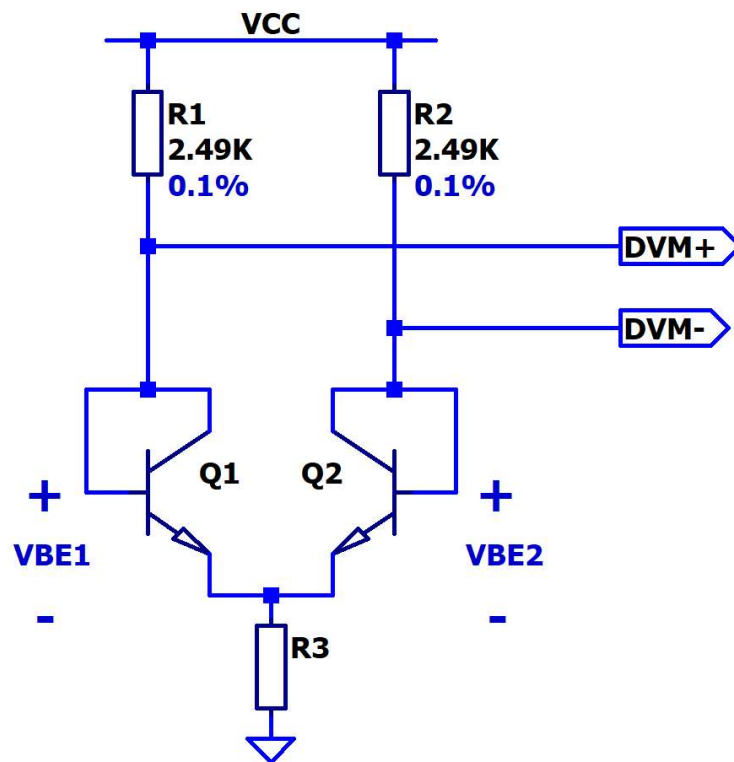
Then let's match transistors for VBE

- Matching reduces distortion in diffamp circuits – linestages, preamps, headphone, power amps
- Matching reduces offset at the output jacks – don't want DC offsets sent into expensive speakers!
- DIYers can match their own transistors, but design-to-a-price-point (penny pinching) audio manufacturers usually cannot; the extra labor cost is unacceptable. So DIY has an advantage.

Amps which benefit from VBE matching

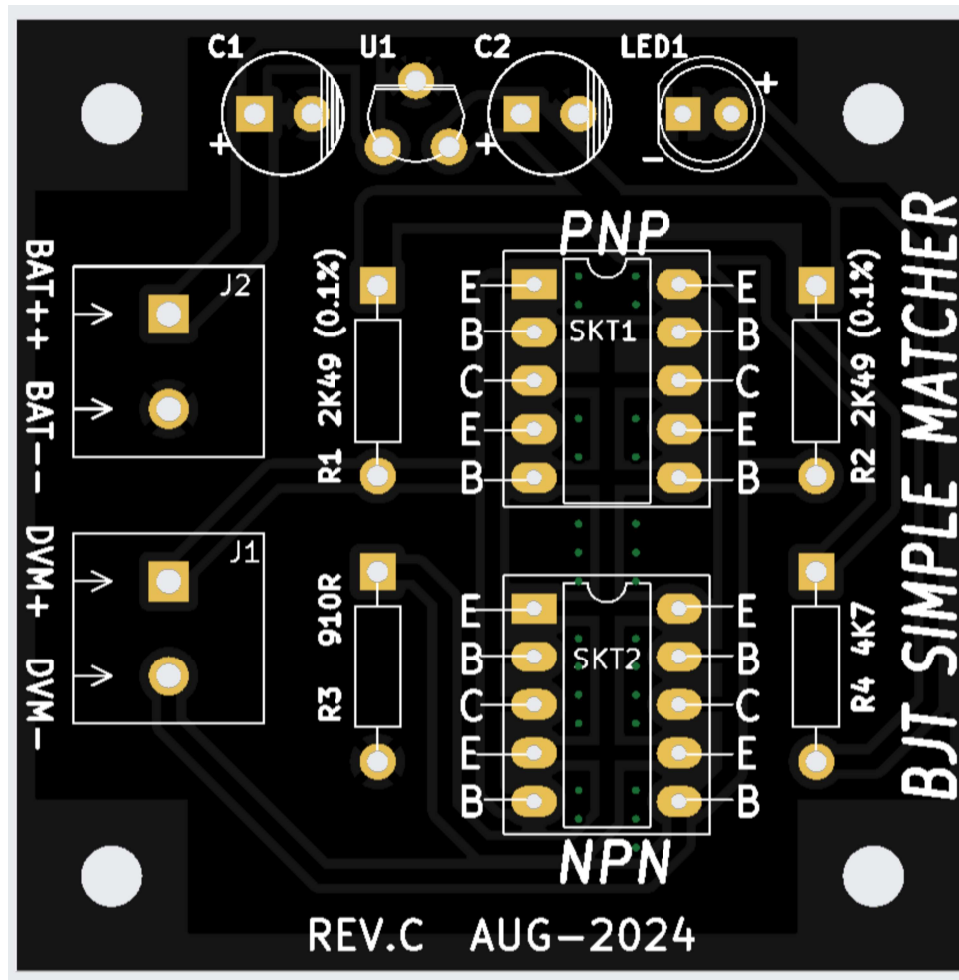
- **Honey Badger** (power amp @ Store)
- **Bulwark** (VFET front end @ Store)
- **Dreadnought** (VFET front end @ Store)
- **Yes It Will Drive An F4** (new bonus PCB released this morning; has its own diyAudio thread)

How to do it (part 1): Use a test-jig



- Precision (0.1%) resistors R1, R2 create identical currents. Price is only \$0.63
- Connect BJTs as 2 terminal diodes; now we can test both NPNs and PNPs with the same jig. Just flip the PNPs upside down
- Now ($V_{BE1} - V_{BE2}$) can be directly measured using a high precision digital voltmeter. The meter reading is exactly the mismatch voltage!

BJT Simple Matcher PCB



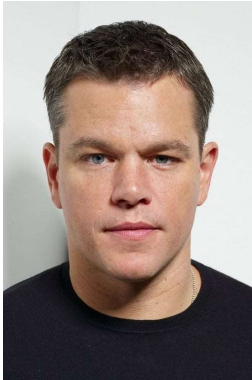
- 9V battery + voltage regulator U1. 3 mA total.
- Unusual DIP-10 sockets can be replaced by pairs of breakaway SIP sockets with 5 pins each
- Plug two PNPs into top socket to match; OR, plug two NPNs into bottom socket to match
- Preferably: use a DVM with good "basic accuracy" (0.1% or better) and which will display tenths or hundredths of a millivolt

The jig's weakness? It's SLOW

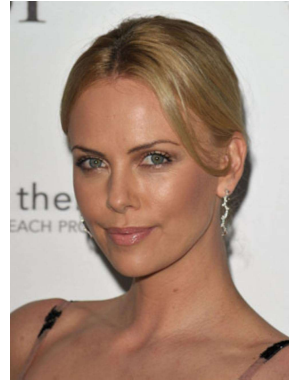
- Although the BJT Simple Matcher is cheap and simple to use,
 - Each matching operation takes 90 - 120 sec before DVM reading stabilizes
 - Why? Because a bipolar transistor's VBE is incredibly sensitive to temperature. And test-jig temperature takes a long time to stabilize.
- Change temperature 1 degree C and VBE changes about 2.2 millivolts(!). To match VBE within 0.5 millivolts you need to match temperature within 0.2 degrees C (!!). It takes a **long** time for transistor temperature to stabilize this accurately

How to do it (part 3): test many BJTs in one afternoon and get lots of matched pairs

- Choose a Reference Transistor from the batch, at random
 - Apply a dot of nail polish as ID
 - Plug it into the left hand side of the socket
 - LEAVE IT THERE THE WHOLE TIME
- For each transistor in the batch: measure VBE mismatch between transistor-under-test and the Reference Transistor.
 - Write this VBE mismatch down and use cellophane tape to attach the transistor to the same paper.
- The cute part: If "A" has the same VBE mismatch to the Reference Transistor as "B"
 - Then "A" and "B" ***match each other***. So we search for pairs of transistors with very close mismatch-to-Reference values. Those are matched pairs!

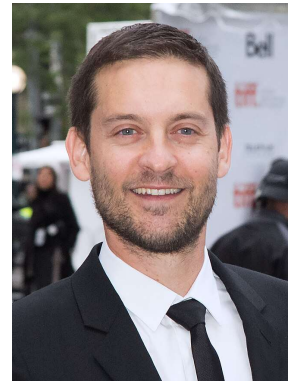
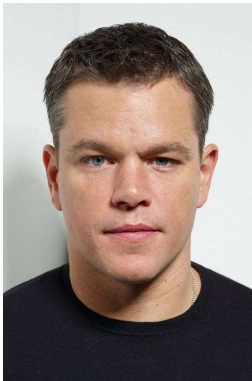


**REFERENCE
UNIT**



**UNIT
UNDER TEST**

- Charlize Theron is 5 years younger than Matt Damon

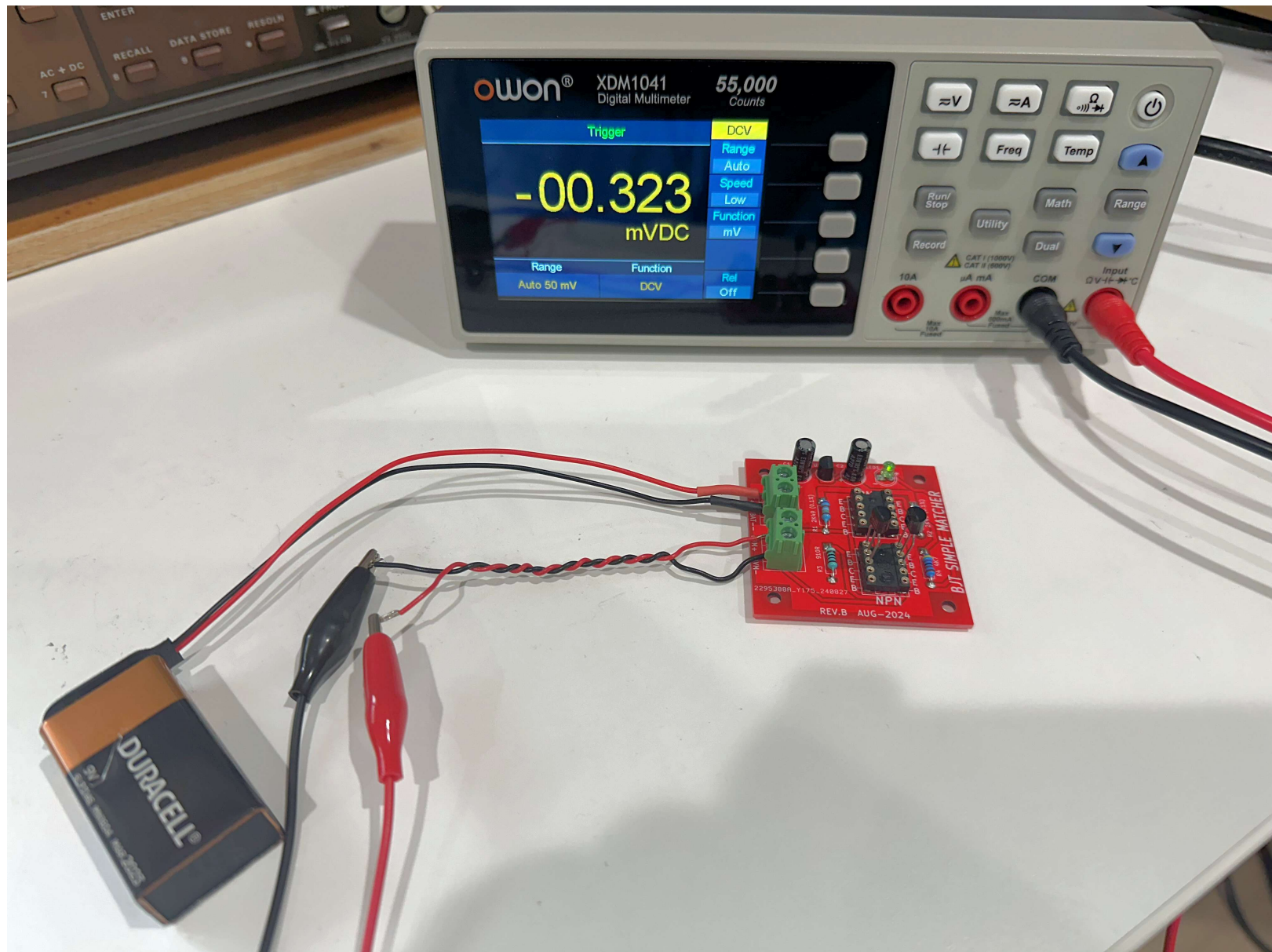


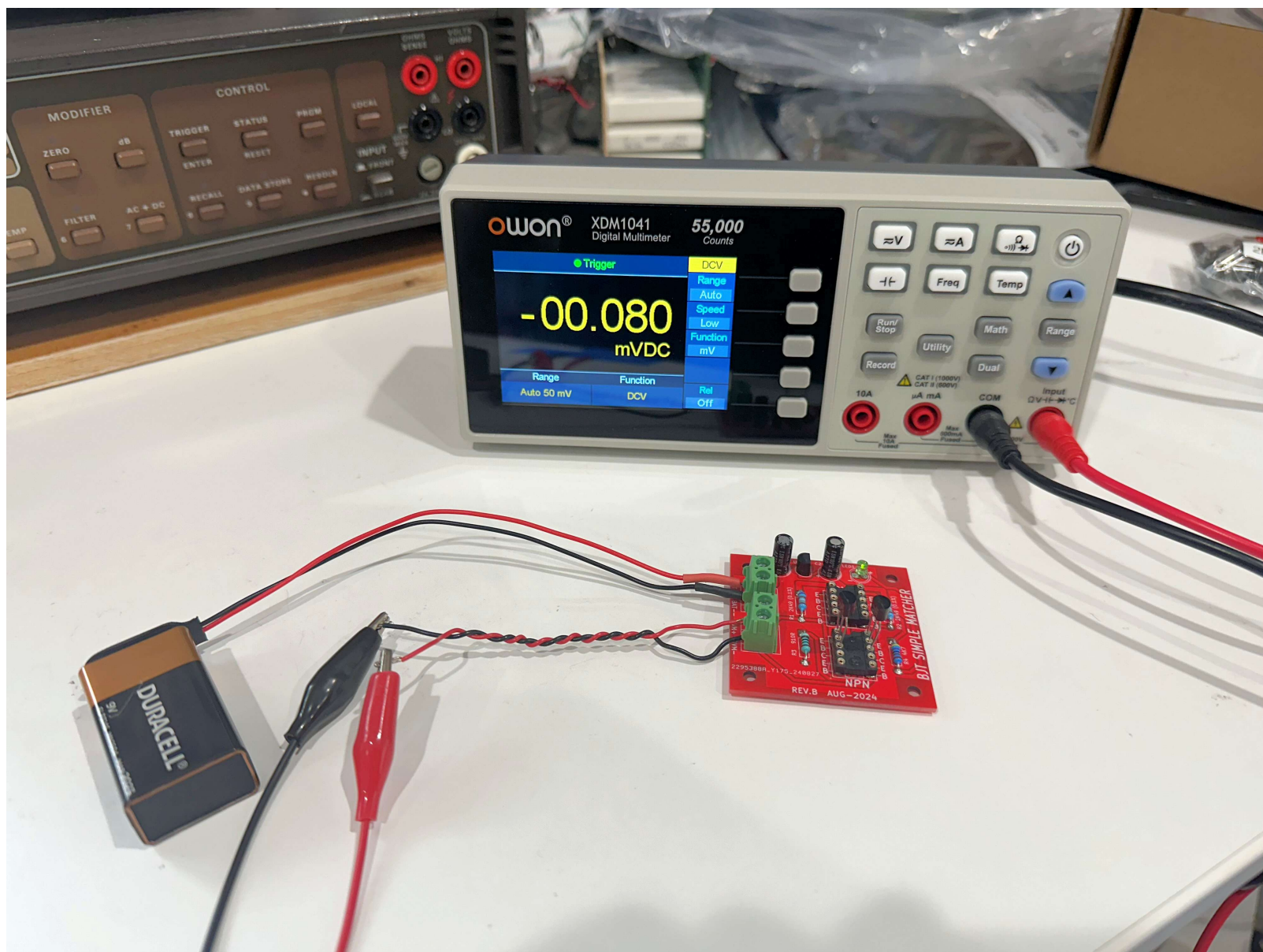
- Tobey Maguire is 5 years younger than Matt Damon

Therefore, Charlize and Tobey are the same age. Their ages ***match***.

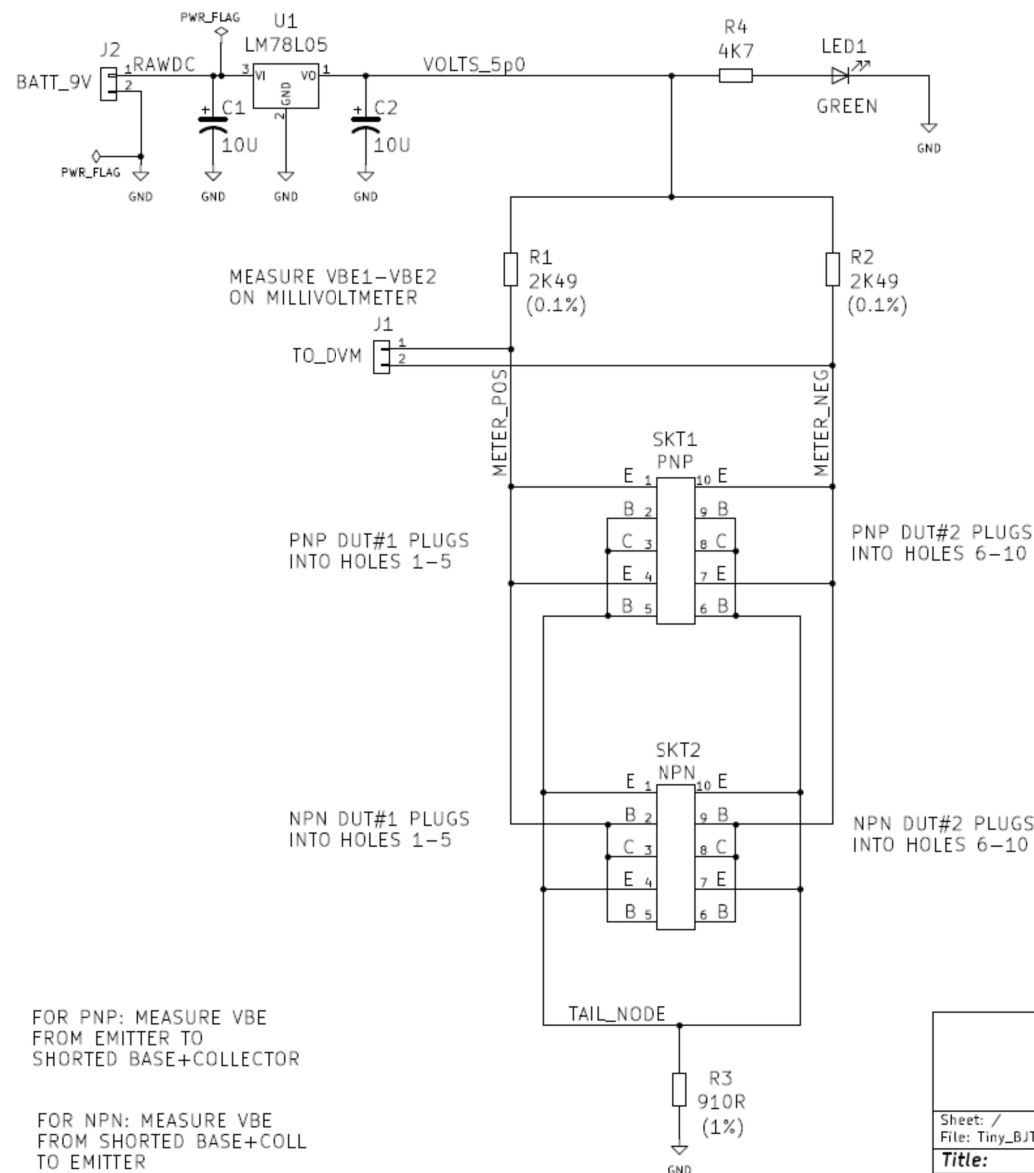
How to do it (part 4) For the skeptical: Verify that those "matched pairs" really do match

- If you don't feel comfortable? Satisfy yourself that the matched pairs identified this way, really and truly are matched:
 - Remove the Reference transistor; plug the two supposedly matched transistors into the socket. Measure VBE mismatch, give it at least 120 seconds to stabilize.
 - Write down the mismatch error.
 - Now, leave everything else exactly the same, but swap (interchange) the two transistors
 - Measure VBE mismatch again, after 120 seconds. Write it down.
 - Calculate $[(\text{WrittenErrorA} - \text{WrittenErrorB}) / 2]$ including signs. THAT is your best estimate of this pair's mismatch. Really! (math @ break)
- After performing this cautious/skeptical verification a few times, you'll gain confidence & trust in the jig; then skip this step.





Rev.C
30 August 2024



INSTALL A REFERENCE TRANSISTOR IN
HOLES 1-5; DEVICE UNDER TEST GOES
IN HOLES 6-10

DVM READS THE DELTA-VBE BETWEEN
REF.TRANSISTOR AND D.U.T.

TAPE THE D.U.T. TO STIFF PAPER
AND WRITE ITS DELTA-VBE BELOW.
REPEAT FOR 20-100 MORE DEVICES
ALL USING THE SAME REF.TRANSISTOR

TWO D.U.Ts "MATCH" WHEN THEY HAVE
THE SAME DELTA-VBE (USING THE SAME
REFERENCE TRANSISTOR). TRY TO GET
MATCHES WITHIN 1 MILLIVOLT OR LESS

BEST PRACTICE IS TO MARK THE
REFERENCE TRANSISTOR WITH A
DOT OF COLORED NAIL POLISH
SO IT IS EASILY IDENTIFIED.
NOW YOU CAN RE-USE IT A MONTH
LATER FOR ADDITIONAL MATCHING

MH1 MH2 MH3 MH4
●●●●

BJT SIMPLE MATCHER

Sheet: /
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Title:

Size: A Date:

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