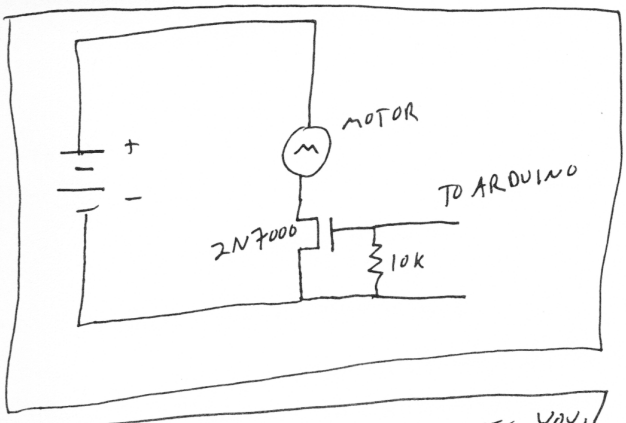
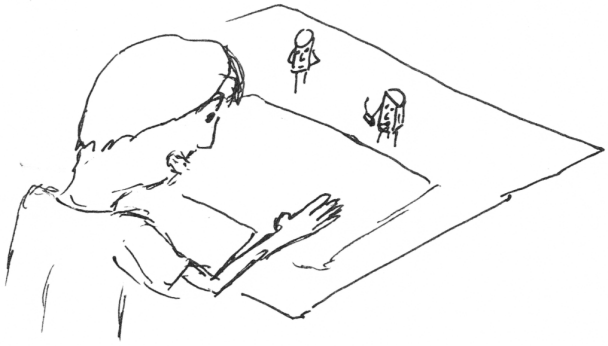
ALEX,
TRANSISTOR TRACY AND CAPACITOR CARL
PRESENT:

EVERYTHING YOU WANTED TO KNOW ABOUT MOTOR CONTROL

BUT WERE AFRAID TO ASK


HI. I'M ALEX.
I'M AN ELECTRICAL ENGINEER.
TODAY, I'M GOING TO TALK ABOUT MOTORS, ALONG WITH MY FRIENDS...
I'M TRANSISTOR TRACY, BITCHES!
SUCK MY THIRD LEAD, CAPACITOR CARL
YOU'RE AN ASSHOLE!
I HATE YOU
GUYS! WE'RE TRYING TO MAKE A COMIC HERE,
CAN'T YOU BEHAVE FOR FIVE MINUTES?
EWW! TRACY JUST TOUCHED ME WITH H/S EMITTER
HA!—
GROSS! I'VE GOT ELECTRONS ALL OVER ME
IGNORE THEM.
LET'S LOOK AT THE SIMPLEST MOTOR OUT THERE: THIS PERMANENT MAGNET DC MOTOR
CONNECT IT TO DC POWER (LIKE A BATTERY) AND AWAY IT GOES!
SWAP THE LEADS, AND THE MOTOR CHANGES DIRECTION.
A MOTOR TAKES TOO MUCH POWER FOR THE ARDUINO TO PROVIDE DIRECTLY.
SO WE'RE GOING TO USE AN ARDUINO TO CONTROL A SWITCH THAT BRINGS POWER TO THE MOTOR
LET'S CONTROL ONE WITH AN ARDUINO
NOW YOU'RE TALKING— TRANSISTOR TRACY
I WANT TO MESS WITH CAPACITOR CARL'S MOM'S VIBRATOR
I HATE YOU-





SO, HERE'S THE BASIC CIRCUIT: WE'RE USING A FET TO SWITCH POWER TO THE MOTOR. THE ARDUINO CONTROLS THE FET'S GATE

HEY DICKFACE

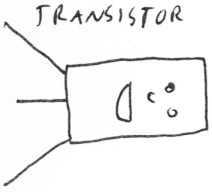
I HATE YOU, TRACY

NOT YOU, CARL. ALEX! THAT FET IS MY HOMEBOY. SHOW SOME RESPECT AND GIVE A PROPER INTRODUCTION

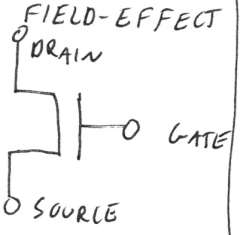
SIGH FINE.

I DON'T KNOW WHY I HANG OUT WITH THESE GUYS

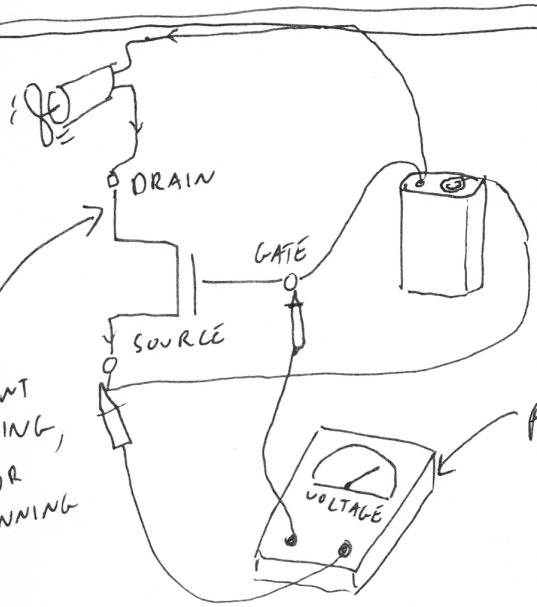
A FET IS A TYPE OF SWITCH. IT STANDS FOR TRANSISTOR



ELECTRONIC FIELD-EFFECT

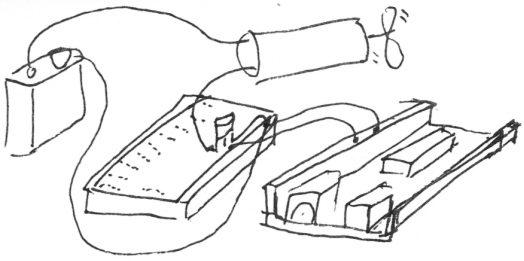


A FET IS A VOLTAGE-CONTROLLED SWITCH. ON AN NFET, A POSITIVE VOLTAGE FROM THE GATE TO THE SOURCE WILL LET CURRENT FLOW FROM THE DRAIN TO THE SOURCE



IT TAKES VERY LITTLE ENERGY TO TURN A FET OFF AND ON.

AND WE CAN USE A SMALL SIGNAL, LIKE ONE FROM THE ARDUINO'S OUTPUT PIN, TO SWITCH A FET AND CONTROL A LARGE LOAD, LIKE A MOTOR



SO HERE, WE HAVE AN ARDUINO CONTROLLING A MOTOR. IF THE ARDUINO'S OUTPUT PIN GOES HIGH (+5V), THE FET ALLOWS CURRENT TO FLOW AND THE MOTOR SPINS. IF IT GOES LOW, THE MOTOR TURNS OFF.

BUT WHAT IF WE WANT THE MOTOR TO SPIN AT DIFFERENT SPEEDS?

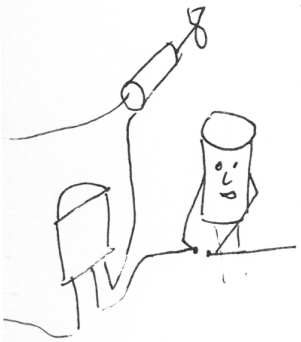
WE COULD FIND BIGGER OR SMALLER BATTERIES AND CHANGE BATTERIES FOR EACH SPEED,

BUT THAT'S NOT VERY ELEGANT...

UNLIKE CARL'S MOM

SHUT UP!

DUDE, YOUR MOM'S A FOX



SO HERE, CARL'S CONNECTING THE VOLTAGE TO THE GATE FOR A SECOND, AND THEN DISCONNECTING IT FOR A SECOND.

THE MOTOR'S MOTION IS VERY JERKY, BUT ITS AVERAGE SPEED IS 1/2 ITS MAX SPEED, BECAUSE WE'RE ONLY GIVING IT POWER HALF THE TIME

AND IF I CONNECT AND DISCONNECT THE WIRES FASTER THAN THE MOTOR CAN PHYSICALLY RESPOND,

THAT JERKINESS GOES AWAY, AND I CAN SMOOTHLY CHANGE THE MOTOR'S SPEED BY CHANGING THE PROPORTION OF TIME IT'S POWERED

THIS IS CALLED PULSE-WIDTH MODULATION, OR PWM.

THE ARDUINO HAS A BUILT-IN WAY OF GENERATING THIS KIND OF SIGNAL

IN THE ARDUINO LANGUAGE, YOU CAN USE THE COMMAND

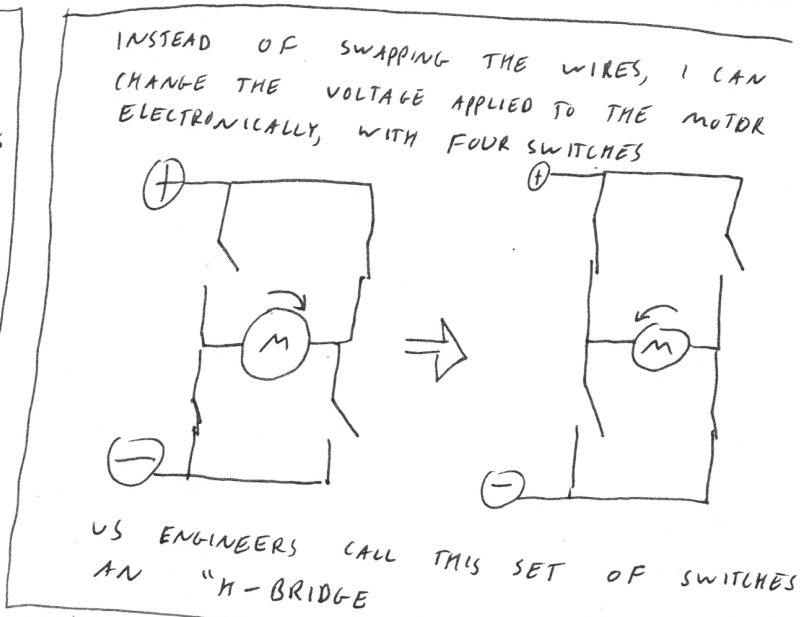
analogWrite(pin, value)

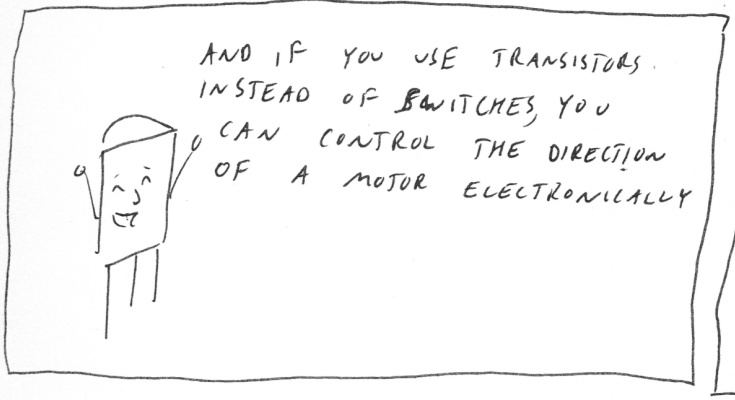
"PIN" IS THE PIN NUMBER YOU'RE USING TO CONTROL THE FET, AND "VALUE" IS A NUMBER REPRESENTING THE MOTOR'S SPEED, WITH 0 BEING COMPLETELY STOPPED AND 1023 BEING FULL SPEED

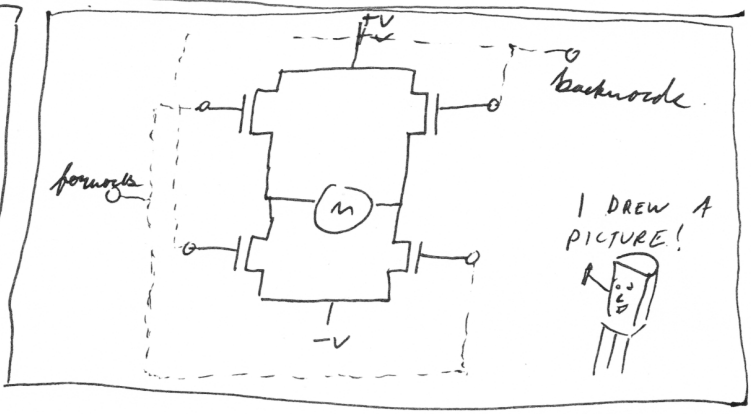
SO NOW WE CAN CONTROL A DC MOTOR'S SPEED

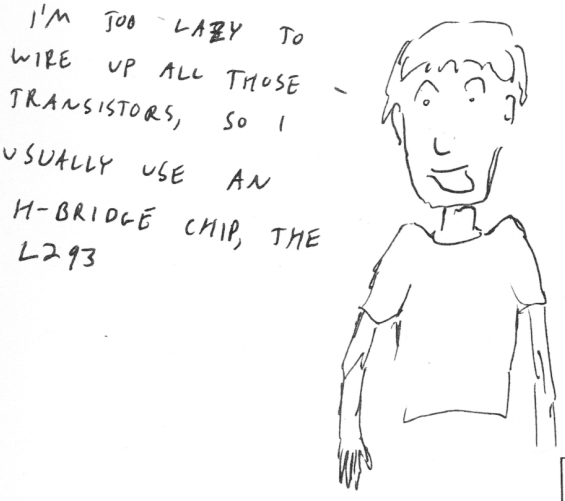
BUT I WANT THE MOTOR TO SPIN BACKWARDS! HOW CAN I DO THAT?

I'M SO VERY GLAD YOU ASKED...



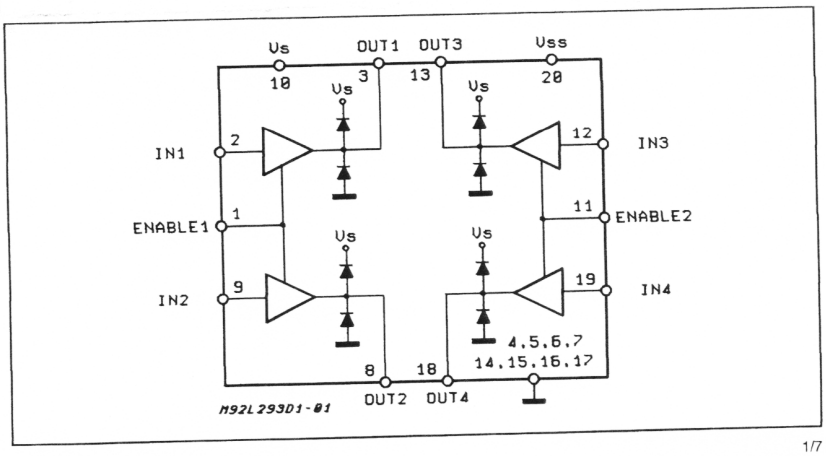






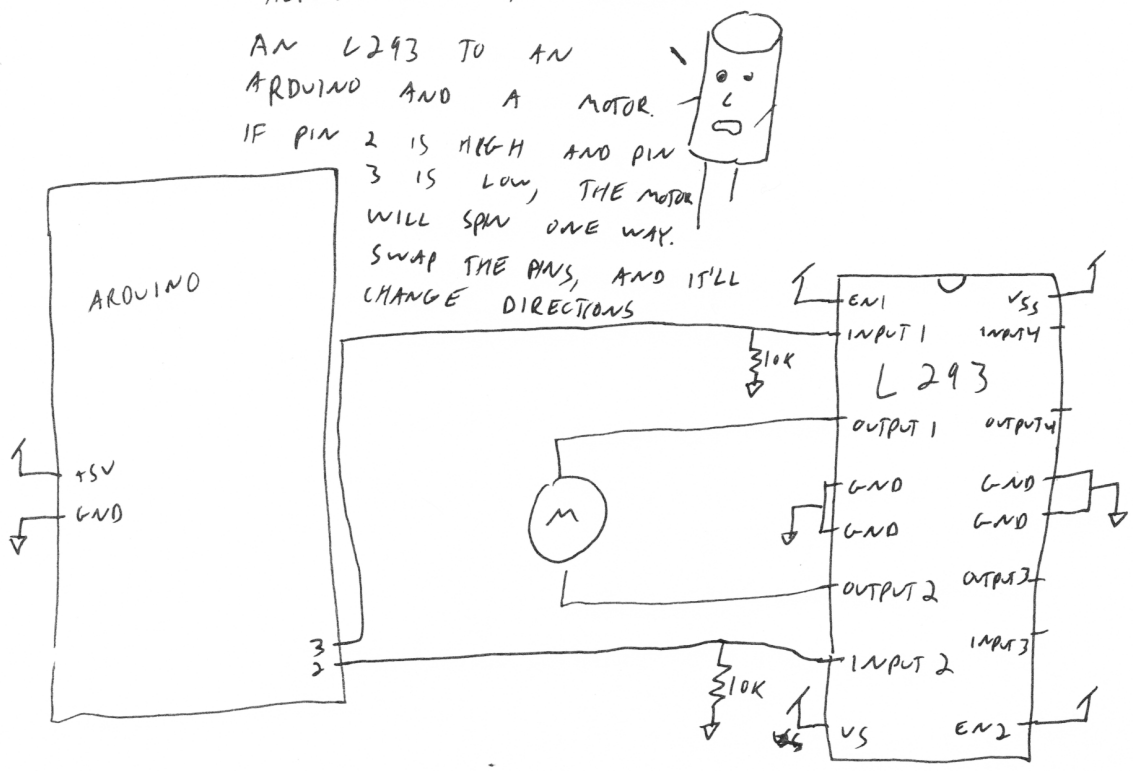
IT'S A LITTLE MORE EXPENSIVE, BUT IT'S VERY CONVENIENT

IT ALSO HAS A HANDY FEATURE CALLED CLAMPING DIODES THAT KEEP CRANKY MOTORS FROM BLOWING UP OUR ELECTRONICS



HERE'S HOW TO CONNECT AN L293 TO AN ARDUINO AND A MOTOR.

IF PIN 2 IS HIGH AND PIN 3 IS LOW, THE MOTOR WILL SPIN ONE WAY. SWAP THE PINS, AND IT'LL CHANGE DIRECTIONS



HEY ASS-BUTT!

DON'T FORGET TO MENTION THAT YOU CAN PWM THE ARDUINO PINS TO CONTROL THE MOTOR SPEED

THE SLACKERS AMONG YOU CAN COPY MY FUCKING OPEN-SOURCE CODE TO MAKE THE SHEEZY HAPPEN ON YOUR ARDUINOS:

THE 10K RESISTORS ARE CALLED "PULL-DOWN" RESISTORS. WITHOUT THEM, THE L293'S FETS DON'T ALWAYS TURN OFF, EVEN IF THE ARDUINO'S PINS ARE LOW

```
analogWrite(3, 900);
digitalWrite(2, LOW);    // SPIN THE MOTOR ONE WAY AT
                         ~90% SPEED

digitalWrite(3, LOW)
analogWrite(2, 200)      // SPIN THE MOTOR THE OTHER WAY
                         AT ~20% SPEED

/* THIS CODE WAS WRITTEN BY TRANSISTOR
   TRACY. ANYBODY USING IT FOR ANYTHING
   OTHER THAN AWESOME PURPOSES IS A TOTAL
   DICK AND HAS A SMELLY VENEREAL DISEASE */
```

HEY GUYS!

LOOK WHAT I FOUND LYING AROUND!

NICE STEPPER, MAN.

SHE LOOKS BIPOLAR TO ME

I DON'T THINK IT'S VERY NICE TO TALK ABOUT SOMEONE'S ISSUES LIKE THAT

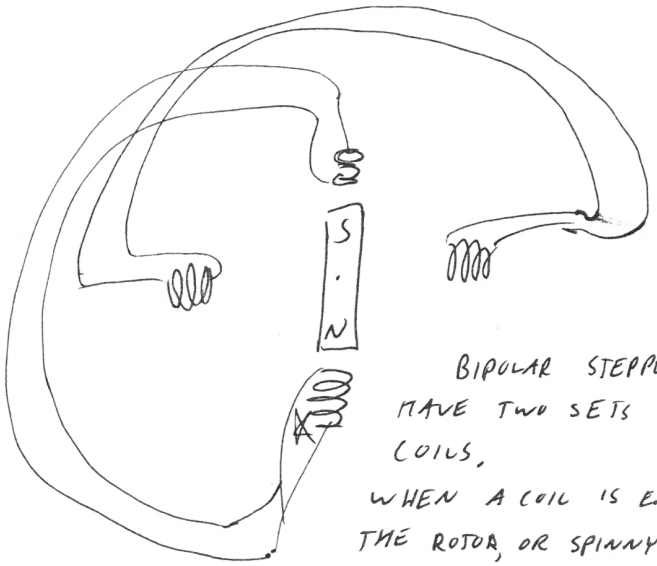
NO, NO.

THAT'S THE TYPE OF MOTOR

IT'S ALL ABOUT HER COILS

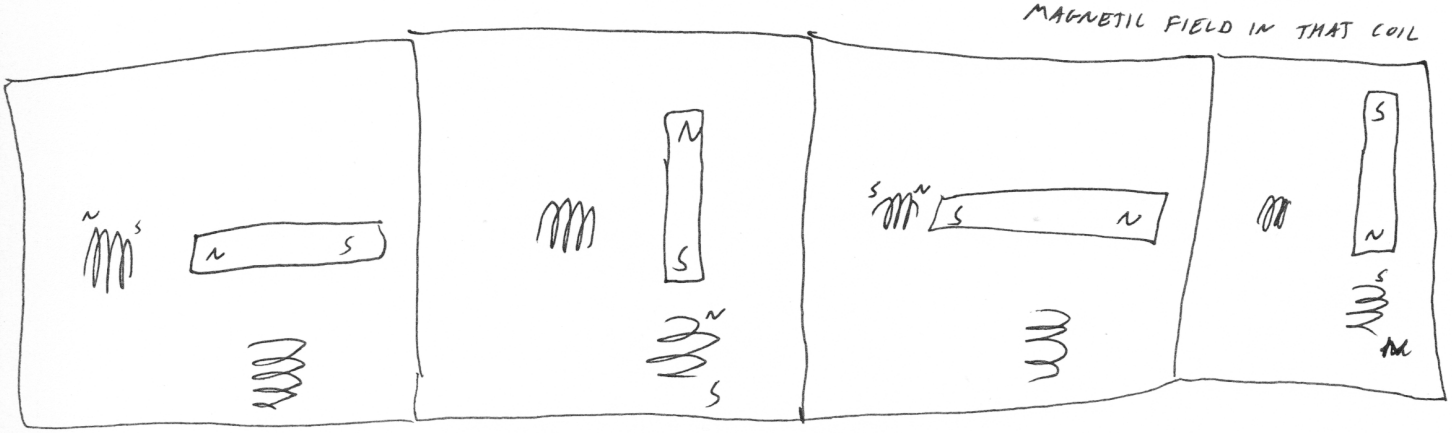
&SNICKER&

BIPOLAR MOTORS HAVE FOUR WIRES - THAT'S HOW YOU CAN TELL



BIPOLAR STEPPERS HAVE TWO SETS OF COILS.

WHEN A COIL IS ENERGIZED, THE ROTOR, OR SPINNY-BIT, ALIGNS WITH THE MAGNETIC FIELD IN THAT COIL



BY "STEPPING" THROUGH THE COILS, WE CAN MAKE THE ROTOR SPIN COMPLETELY AROUND

HOORAY!

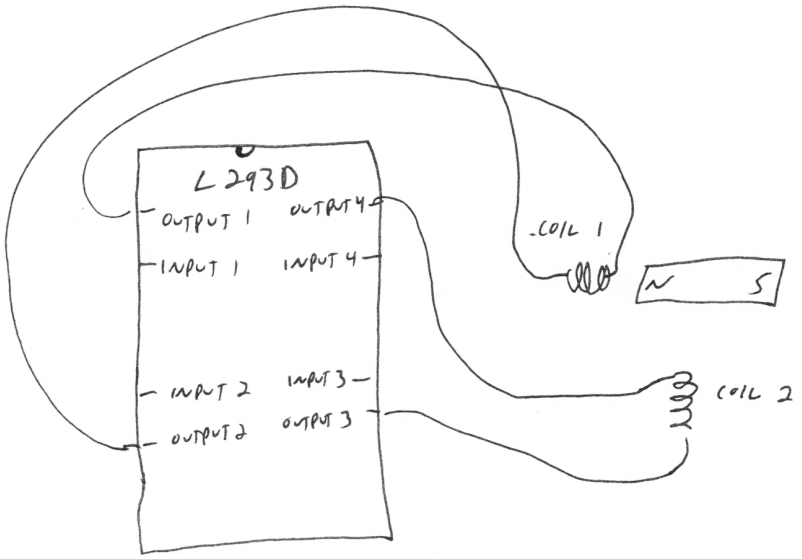
WITH BIPOLAR STEPPERS, WE HAVE TO CHANGE THE DIRECTION OF CURRENT THROUGH THE COILS.

UNIPOLARS ARE A LITTLE SIMPLER. THEY HAVE FOUR SETS OF COILS, AND WE ONLY HAVE TO TURN EACH ONE ON IN ONE DIRECTION

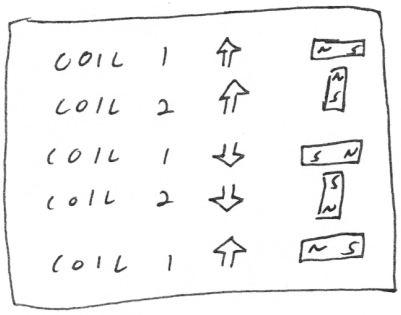
FORTUNATELY, WE JUST LEARNED HOW TO MAKE CURRENT GO IN BOTH DIRECTIONS THROUGH A COIL

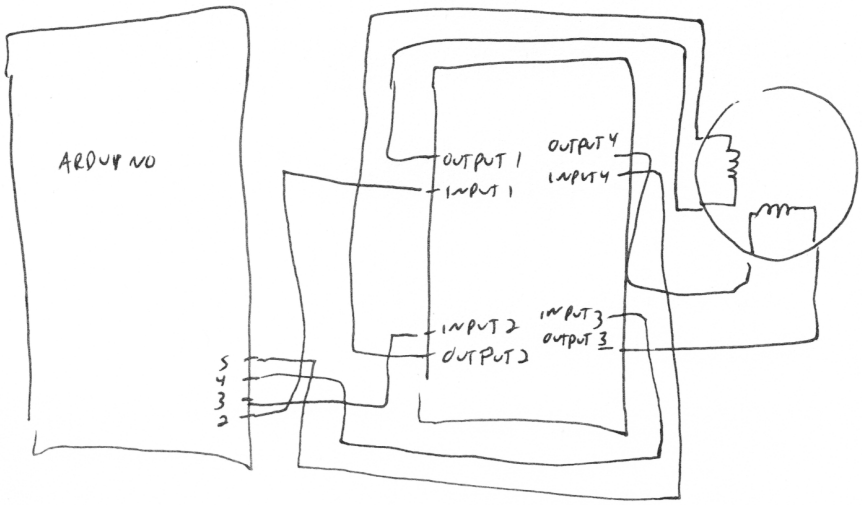
REMEMBER THE H-BRIDGE?

WE CAN USE IT TO CONTROL A STEPPER, TO



NOW, WE JUST HAVE TO TURN THE COILS ON IN A CERTAIN ORDER, AND WE CAN MAKE THIS PUPPY SPIN






```
digitalWrite(2, HIGH)
delay(10)
digitalWrite(2, low)
digitalWrite(4, HIGH)
delay(10)
digitalWrite(4, LOW)
digitalWrite(3, HIGH)
delay(10)
digitalWrite(3, LOW)
digitalWrite(5, HIGH)
delay(10)
digitalWrite(5, LOW)
```