Spal Radiator Fan Installation with PWM Speed Control

Adnan Merchant

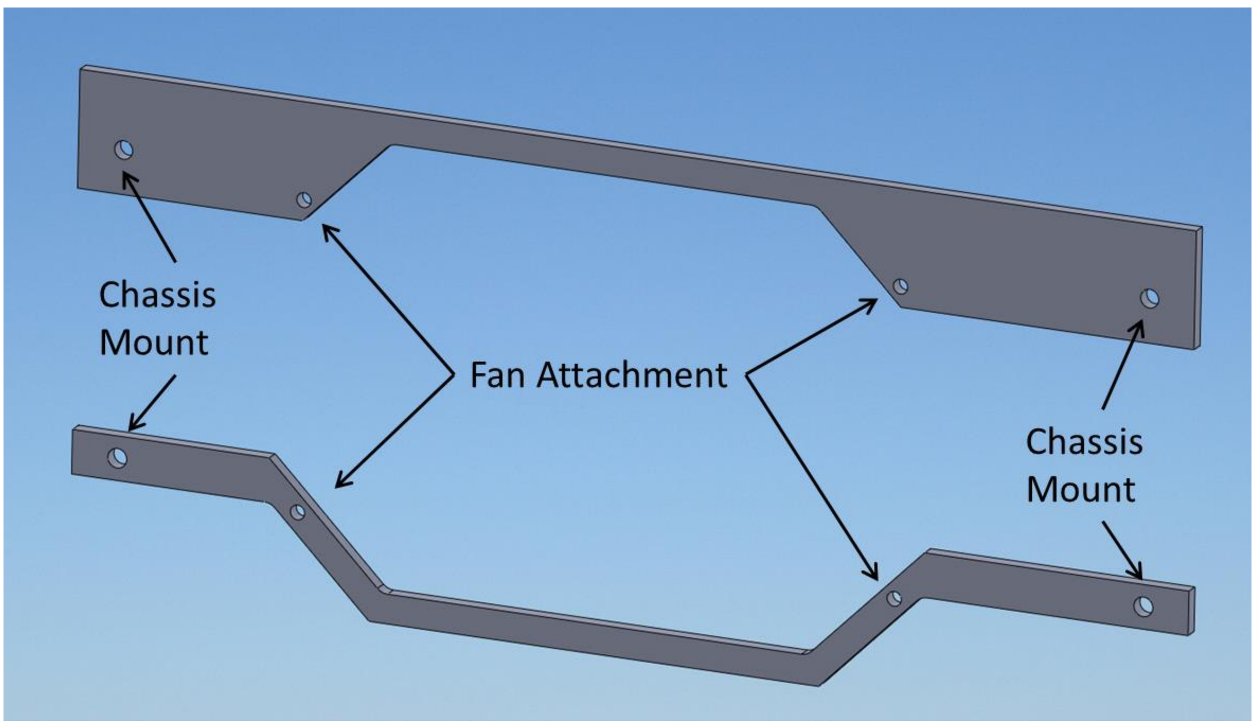
10 January 2019

The objective of this modification was to install an electric radiator fan with variable speed control. Specific design goals were as follows:

- Minimize loss of radiator frontal area
- Mount fan flush with the radiator
- Minimize axial motion of the fan assembly under driving conditions
- Implement high-frequency PWM speed control
- Control fan speed as a function of radiator outlet temperature

Mounting Brackets

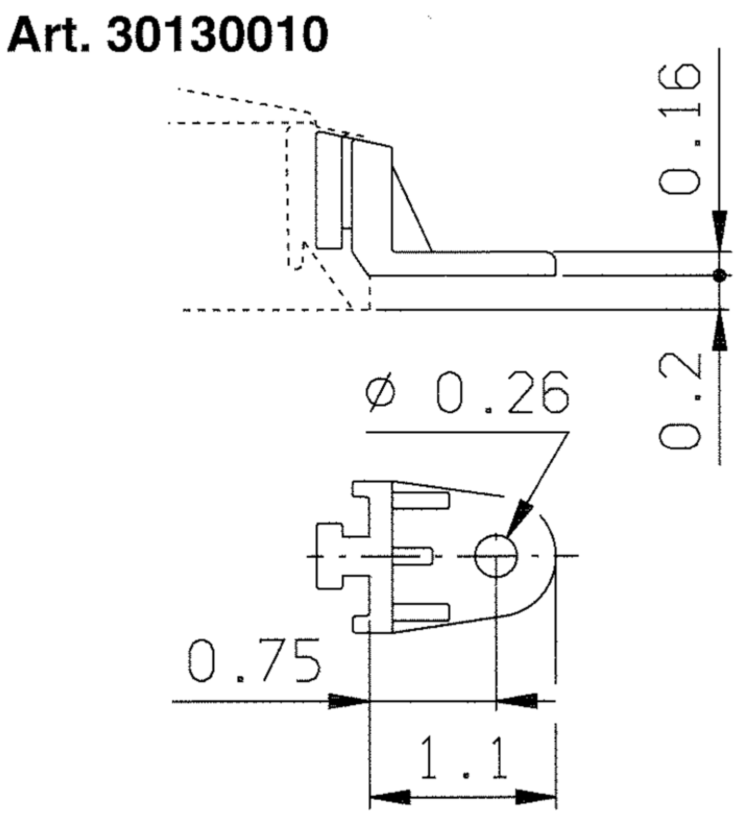
These brackets use the existing radiator mounting bolts. The image below shows the upper and lower brackets, made of 3/8" thick aluminum. The upper bracket could also have been shaped like the "batman" lower bracket for even better airflow, but I got lazy. All fabrication was done with a table saw and hand drill.



The picture below shows the brackets dry-fitted with the radiator removed.

Fan Mounting

The fan I used is the 12" Spal 30102029 pusher. To attach it to the brackets, I purchased Spal's 30130010 mounting clips. This allows the front face of the fan to be completely flat, with no interference from screw heads. The illustration below from Spal shows the clip.



The fan bolts onto the brackets using the four clips. Note the use of washers between the clip and bracket in the picture below, to position the fan at the radiator face.

Speed Control

While on/off control will do the job, it is inefficient and puts a lot of stress on the electrical system. Plus, a fan roaring at full throat is pretty noisy. I decided to use pulse width modulation (PWM) to vary the speed of the fan. By monitoring the coolant temperature at the output of the radiator, the PWM can be set up to regulate that temperature automatically.

The challenge with PWM is that aftermarket controllers typically provide a 100 Hz drive frequency, and for good reason. Making a reliable, high-frequency, high-current driver is expensive and technically challenging. The Spal fan and many others with brushed motors, like to run at much higher frequencies, around 20 kHz. When driven this way they run cool, quiet and happy.

To monitor the radiator outflow temperature, I used BMW 12 62 1 288 158 NTC temperature sensor installed in the lower radiator hose, using Ireland Engineering's adapter. Many thanks to Chargin on the FAQ for sending me one of these!

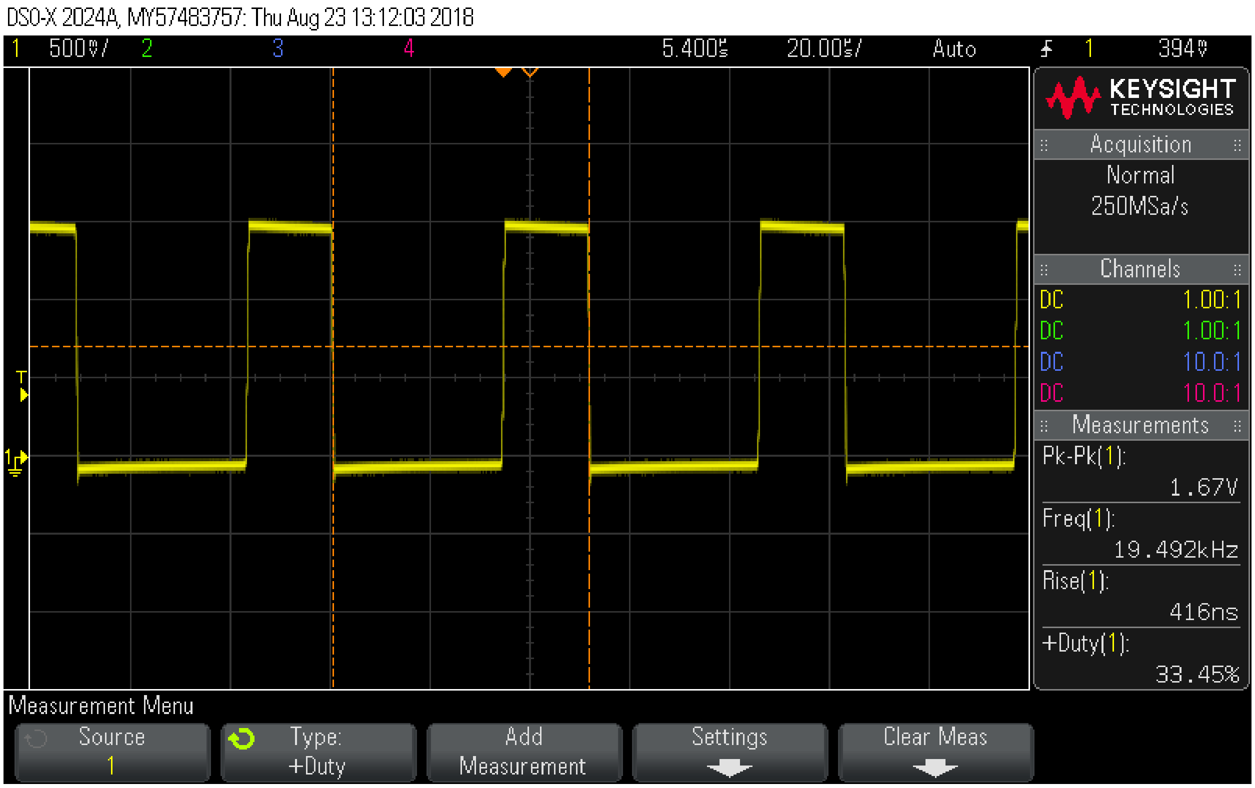
The Junkyard Solution

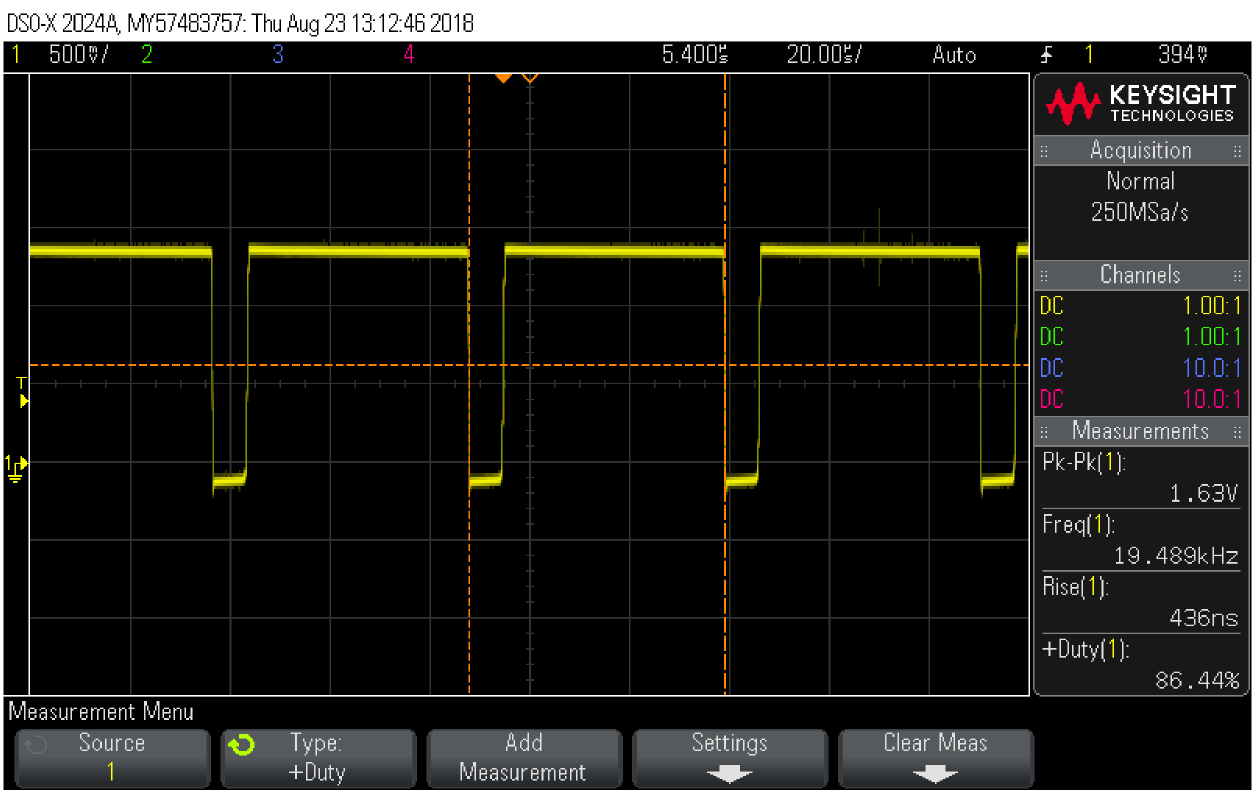
It turns out that in the mid-2000's, car manufacturers scrambled to install PWM fan control because the EPA gave them a credit on the CAFE requirements, since it reduced fuel consumption. Their solution was to add a PWM module that accepted a 100 Hz PWM input and put out a 20 kHz drive to run the existing fans. These were found in several cars, from Ford to GM to Mercedes and look like they came from the same source. The module is a brute as it can handle the 37 amp load of a C6 Corvette fan. I used the one from a 2008 Ford Fusion. Make sure you get the wiring pigtails as well. I mounted mine using the two existing holes in the front apron panel as the holes in the module lined up almost perfectly.

These modules have an interesting PWM input requirement, as the table below shows. Between an input of 10% and 90% duty cycle, the output varies linearly.

Input Duty Cycle (100 Hz)	Output Duty Cycle (20 kHz)
< 10%	OFF
10%	33%
90%	100%
> 90%	OFF

To give you an idea of how good the module's drive waveform is, below are a couple of scope shots at different output duty cycles while driving the Spal.



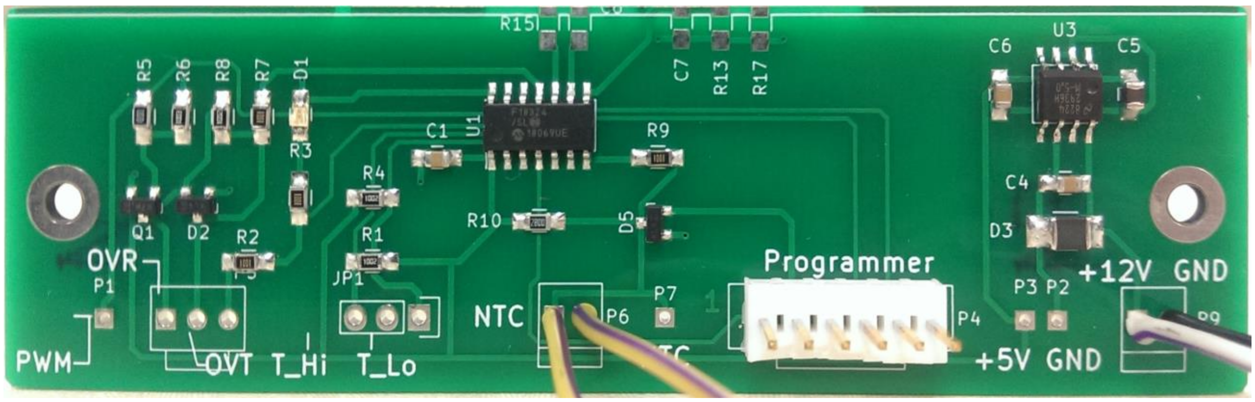


Controlling the PWM Module

Now that the requirements were understood, the next task was to provide the correct input waveforms. After much deliberation, I concluded that the easiest way to do this was to use a microcontroller to do all the logic. The logic is simple:

- 10% duty cycle at 75° C (turn on)
- 90% duty cycle at 90° C (full speed)
- Linear in between

The circuit also adds a couple of features, such as a switch input to turn the fan on at full speed at any time as well as an LED output for an over-temperature condition (warning light). Here's the PCBA, which could be made much smaller and packaged with a sealed connector. This circuit can be mounted in the engine compartment as the components are rated for automotive use. I have tucked mine away near the charcoal canister.



Wiring

This is perhaps the easiest part of the entire project. The module has five connections:

Terminal	Function
M+	Fan +
30	Battery – fused, 30 A (unit draws less than 50 µA when off)
31	Chassis
M-	Fan -
PWM	PWM Input (from PCBA)

WARNING: DO NOT connect M- or the fan's negative terminal to chassis!!

The PCBA also has connections that need to be addressed:

- Ignition switched 12 volts
- Chassis
- Temperature sensor (2 wires)
- PWM output to Ford module

Since the pigtails I hacked off the donor car were long enough, I could run the wires without splicing. I used a 30 amp MIDI fuse to feed the fan directly from the battery (I had previously installed an e36 junction box which offered a convenient hook-up point, as shown below. It was also possible to feed the wires along the existing harness for a clean look.

Does it work?

I am impressed by the performance of the Ford module. It has built-in soft start and soft shutdown such that it ramps up and down gradually during any speed change command. Even if asked to go to full speed from a stop, it spins up gradually and keeps the load on the electrical system to a minimum. I find that the fan rarely needs to come on during normal driving but I haven't tried it in the heat of summer. When it does come on, it is so quiet as to be unnoticeable, what I call "whisper mode".

For those with an EFI controller, the setup is even easier. Just connect the temperature sensor to a spare analog input and the Ford module to a spare PWM output. No microcontroller PCBA needed.

I have also attached this document as a pdf that you can download for easier reading.