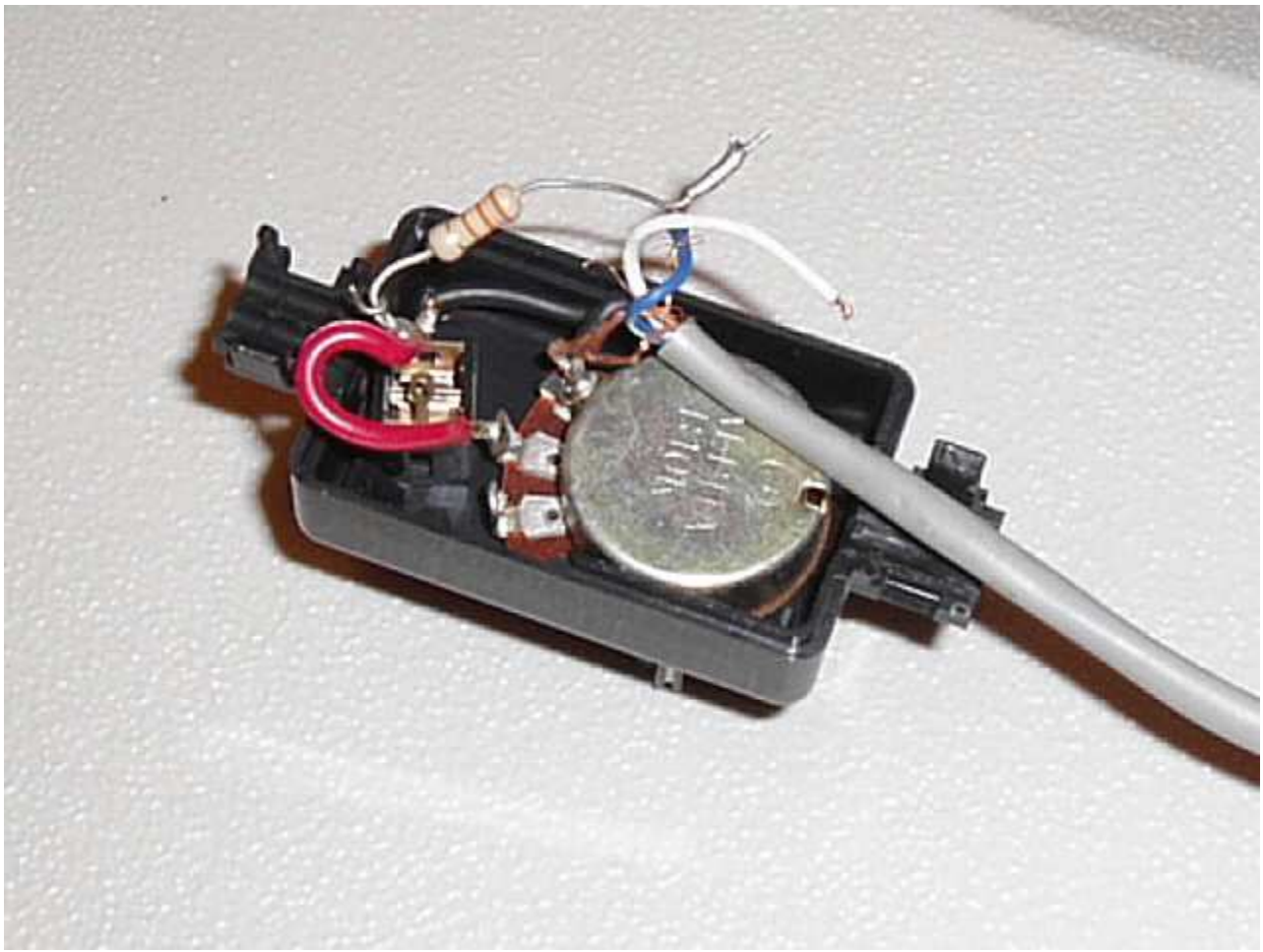
7A-GE STREETDYNO TUNING PROCESS

First things first, I want to thank Orion at www.whyturbothat.com for inspiring me to do two things – properly tune the engine, and document the changes I made and the effect they had on the engine on this page.

Anyway, I built the car and then drove the car around for almost a year after I got it smogged without really touching it. I guess I just wasn't really excited about getting into it again, so I left it as it had been. It ran well enough and was entertaining to drive, so there was no real reason to mess with it, right?

Then, almost on a whim, I decided to look into Streetdyno again. Streetdyno is a computer program that lets you record a sound file from your ignition system, and then converts that sound file into horsepower and torque curves by comparing your engine's acceleration to the car's other properties (weight, aerodynamic drag, drivetrain loss, etc). It's a pretty sophisticated program and even has inputs for weather conditions. Obviously it cannot be used to compare directly with actual dyno numbers, but it is definately repeatable and reliable and is a great tool for evaluating changes you make to your vehicle without the cost and time of visiting a conventional dyno. Once I got a laptop, I decided to try Streetdyno again, recording the ignition sound file directly onto the laptop with Audacity, a free audio editing program. A couple of people have asked how to connect the laptop to the car so I've added a couple of pictures of the voltage divider I built to do that.

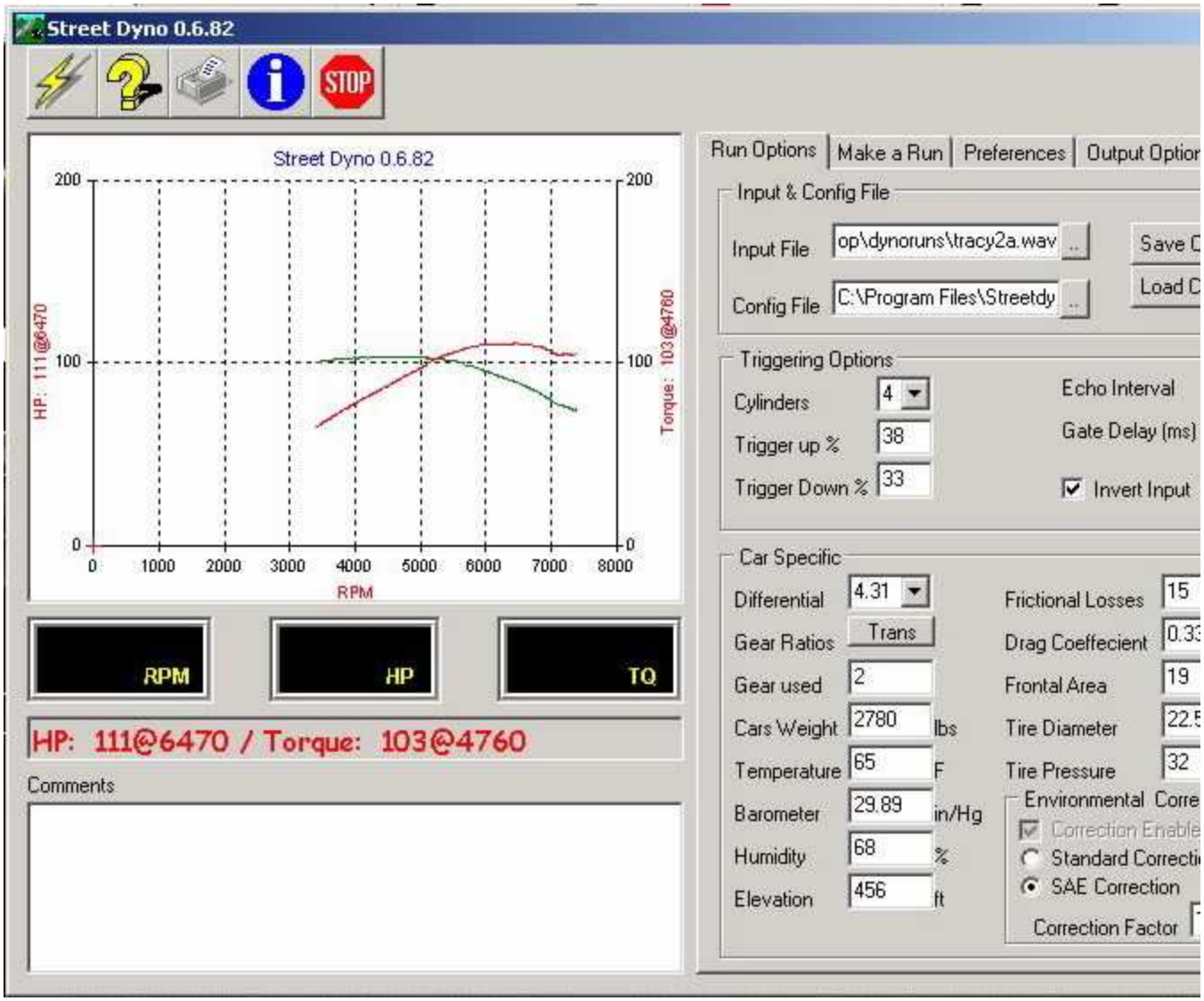
The assembled voltage divider. I used a plastic box pulled from a prehistoric car stereo wiring harness. The headphone jack is the same as the one on the laptop so a simple cable from Radio Shack connects the two. The blue wire has a 1/4" spade connector and goes to the IG- connector on the outside of the diagnostic connector, and the clear one goes to the E1 (earth) terminal inside the diagnostic connector.



1) Black wire is from mounting ring on headphone jack (i.e. innermost terminal on cable) to one side of potentiometer. This is also connected to the wire that goes to the E1 terminal.
2) Red wire is from center terminal on pot to either of the other terminals on the jack (doesn't matter which).
3) Resistor is from headphone jack terminal (shared with red wire) to wire connected to IG- terminal. I don't know whether the orientation of the resistor is important, but it does work in this configuration. Be sure all circuits are insulated from each other to avoid interference (or worse).

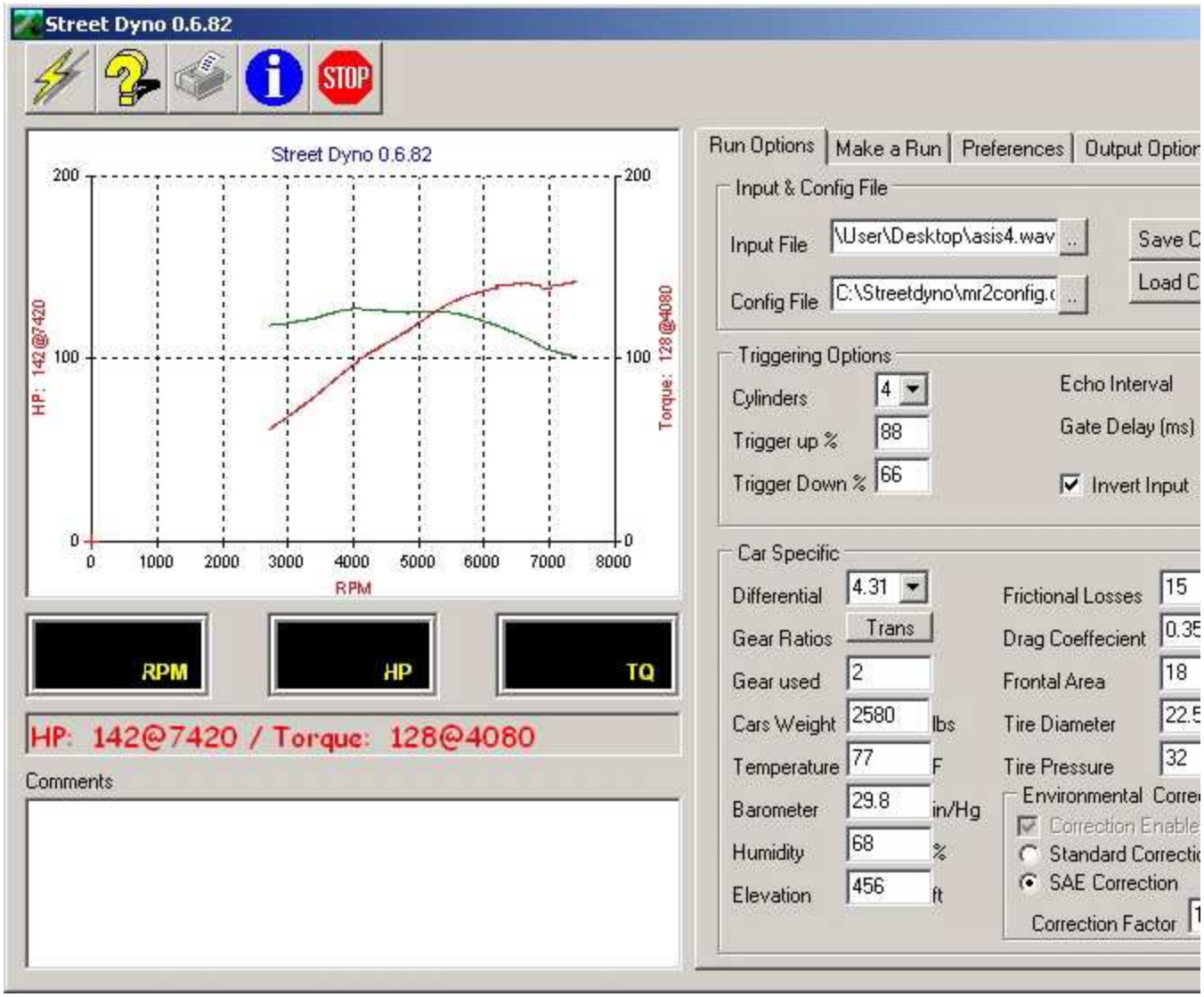
One thing I wanted to do was compare my car to a stock 4A-GE. I wanted to know what my time and money had done for me. Luckily, a co-worker had a bone-stock '86 MR2 that had just had a recent tune-up. It was running really well, so we made several runs in it. It's important to make several runs over the same stretch of road at each step; a gust of wind or other factor can really skew your results if you're relying

on only one sample. We weighed the car first and estimated 15% drivetrain loss, since that seems to be a pretty reasonable figure for most cars with a manual transmission. I allowed his car a .33cd since he has the full factory aero kit, vs. .35 for mine with no spoilers. I am trying to be conservative so I don't artificially inflate the results. Just like the AE86 did years ago, it produced numbers remarkably close to what the factory quoted. And when I changed the drivetrain loss to 0% to simulate wheel horsepower, the numbers pretty closely matched what people usually get with a stock AW11 on a Dynojet. We actually tested his car after I tested mine the first time, but I am showing the stock car first to establish a baseline.



Stock AW11: 111hp at 6470rpm, 103ft/lb at 4760

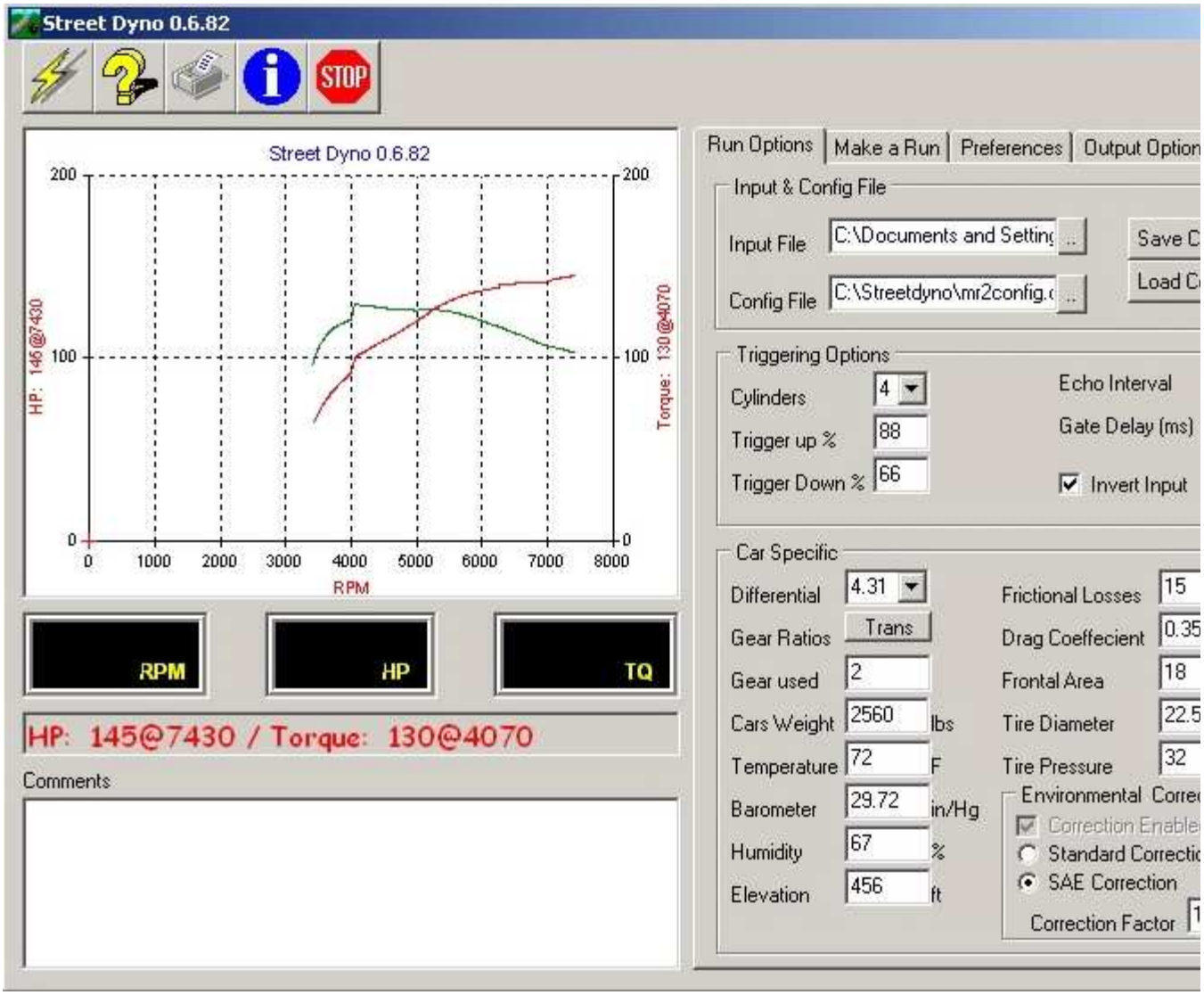
I also weighed my car and tested it. Since it has the same drivetrain, I used the same 15% loss figure. I must say I was both pleased and disappointed with the initial results. I had hoped for more but expected to be more disappointed than I really was.



First run, in as-is configuration: 142hp at 7420, 128ft/lb at 4080

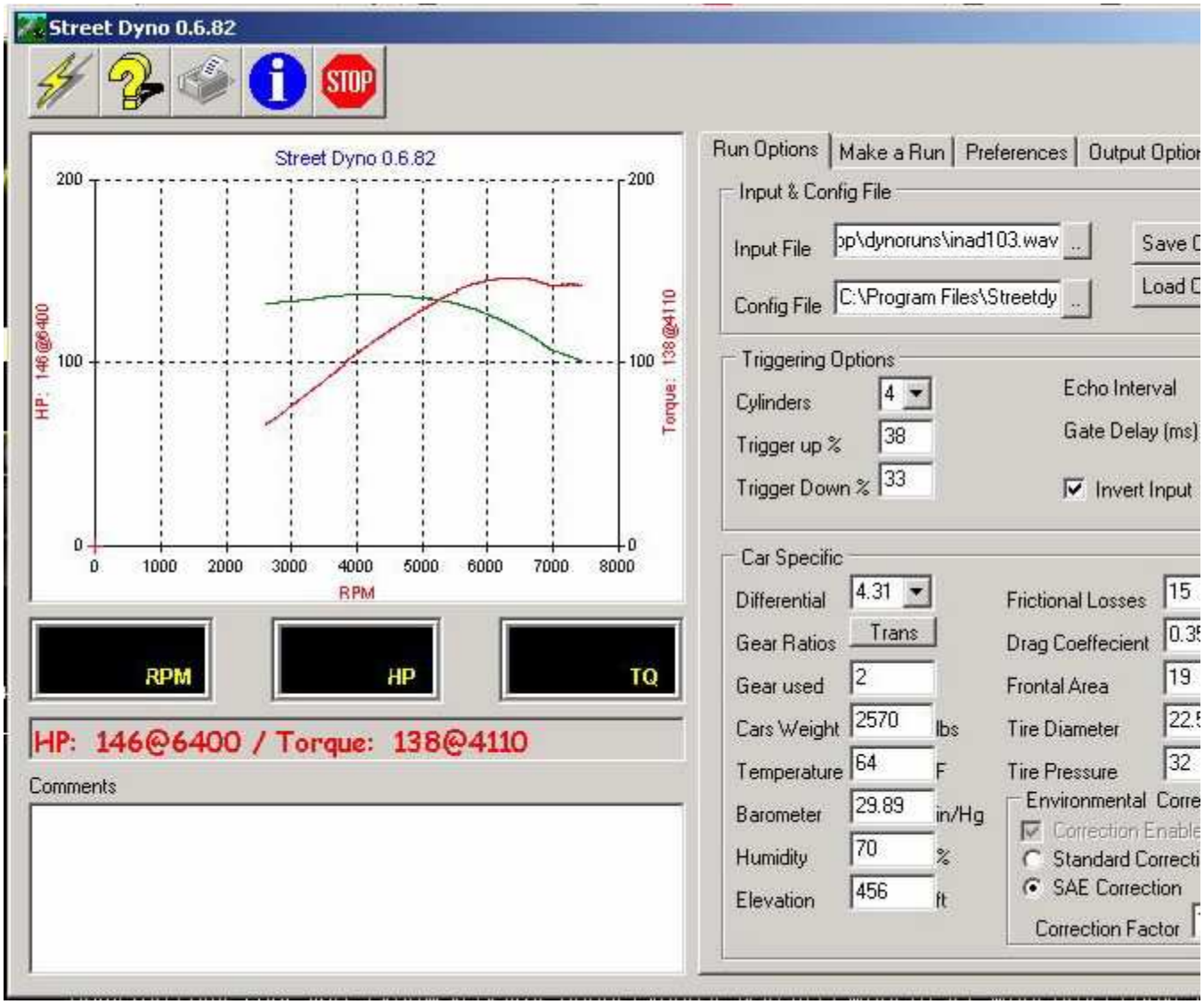
Something to note here: The horsepower curve fell off sharply at redline (7500) unless I trimmed the .wav file back. I trimmed it back until the dropoff went away, and discovered a big rise in power towards redline. Unfortunately I wasn't smart enough to test this out more thoroughly, because it turns out to be bogus, some unfortunate accident that does not reflect the engine's true output. When the peak power starts showing up at lower RPM, you'll know I have stopped overtrimming the .wav files.

The first variable I started testing was ignition timing. This engine has detonated since day one, and requires some very careful driving to avoid pinging it to death, so I had retarded the timing a few degrees to avoid that. Luckily it doesn't detonate on full throttle, so if it starts to rattle, I can usually floor it to make the noise go away. I started with the ignition timing turned way back to TDC and advanced it from there. It liked all of the 9 degrees BTDC I gave it, but I stopped there because the detonation was getting harder to drive around.



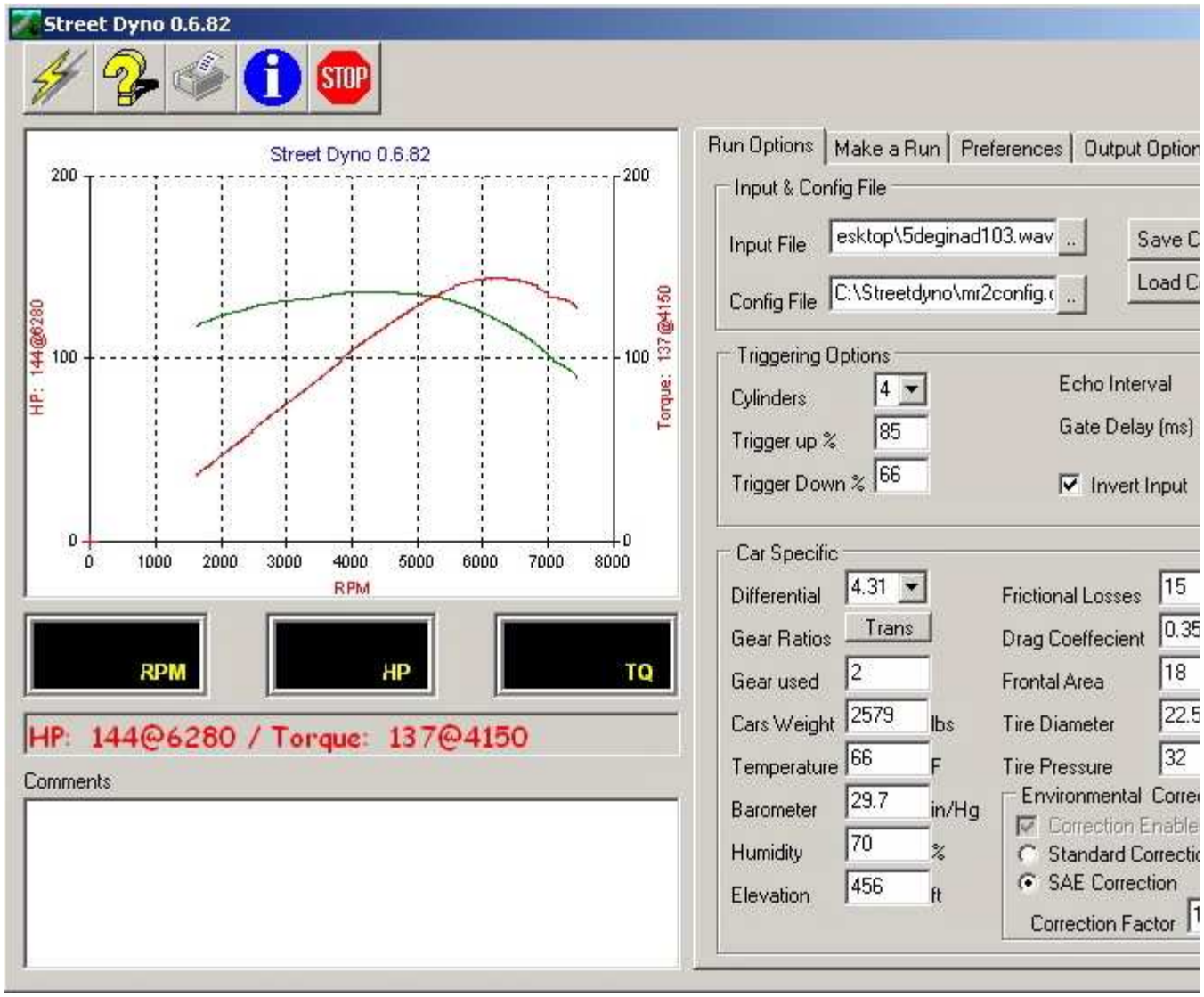
Ignition timing at 9 degrees BTDC: 145hp at 7430, 130ft/lb at 4070

Next I messed with intake cam timing. I advanced the intake cam in two-degree increments (degrees of camshaft rotation; each degree at the camshaft equals two degrees at the crank) a total of about 10 degrees from where it had been and realized a huge jump in torque as well as a little horsepower. I also found more detonation, which reminded me why I had retarded the intake cam so much in the first place (to bleed off cylinder pressure on the compression stroke), and this is where I realized that I had been fooling myself with the false horsepower peaks at redline. The torque curve was getting stronger from 2000 RPM on up and was very flat, and it was exciting to see the results start coming in! At this point the idle was starting to get just a tiny bit choppy, though drivability was totally unaffected.



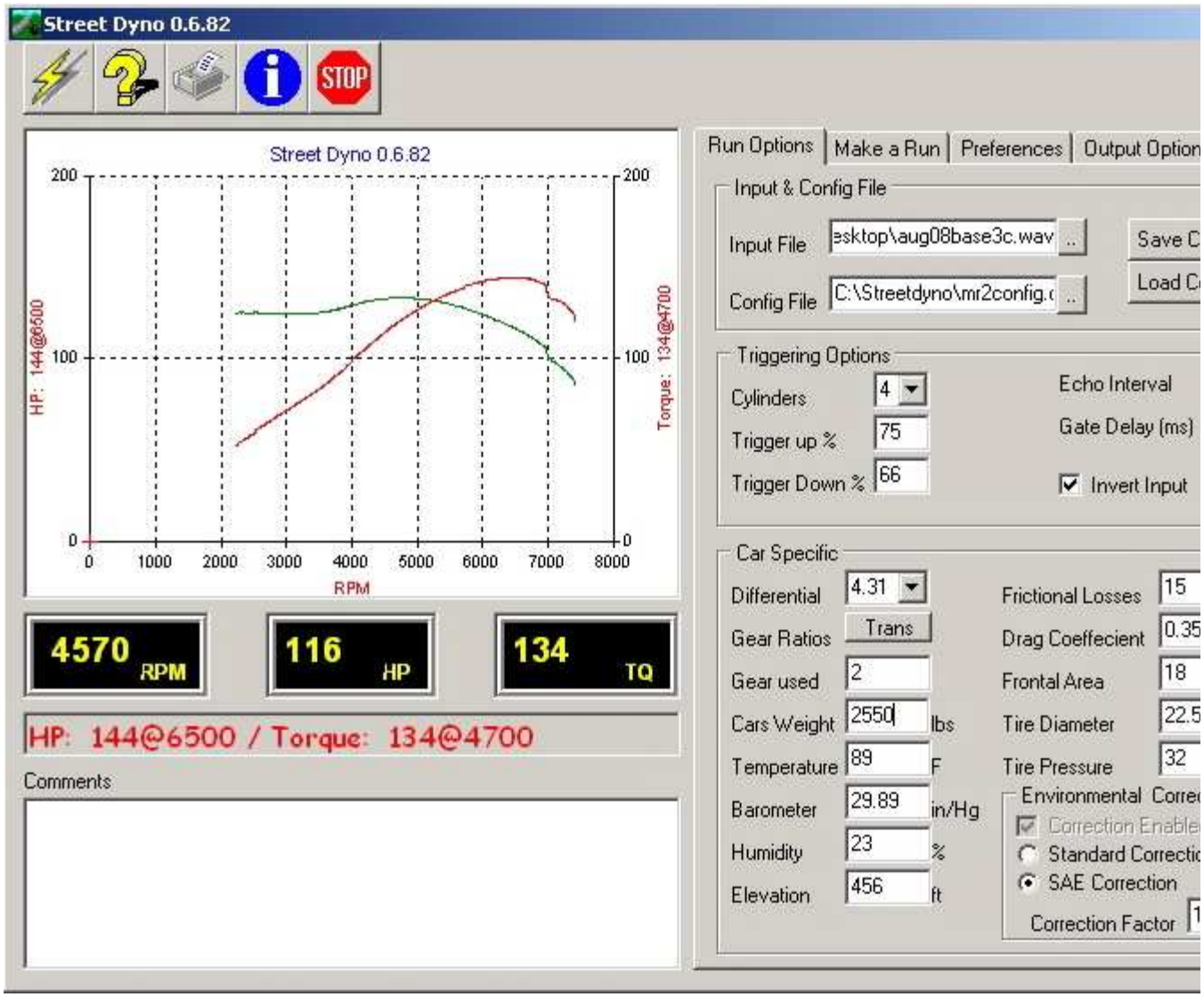
Intake cam timing advanced 10 degrees (at cam): 146hp at 6400, 138ft/lb at 4110

I decided to retard the ignition timing back to five degrees BTDC to help reduce detonation. The peak numbers didn't drop much, but torque fell by two to three ft/lb everywhere around the peak. That brings up another point: when the torque curve is very flat near the peak, Streetdyno seems to pick an arbitrary point on the RPM scale, anywhere within that flat area, to label as the torque peak. In other words, if the engine produces 140 fl/lb of torque between 4100 and 4450 rpm, it's anyone's guess what the program will call the peak. But since you can hover the cursor over the graph and get horsepower and torque readings at any RPM, it's not a big deal.



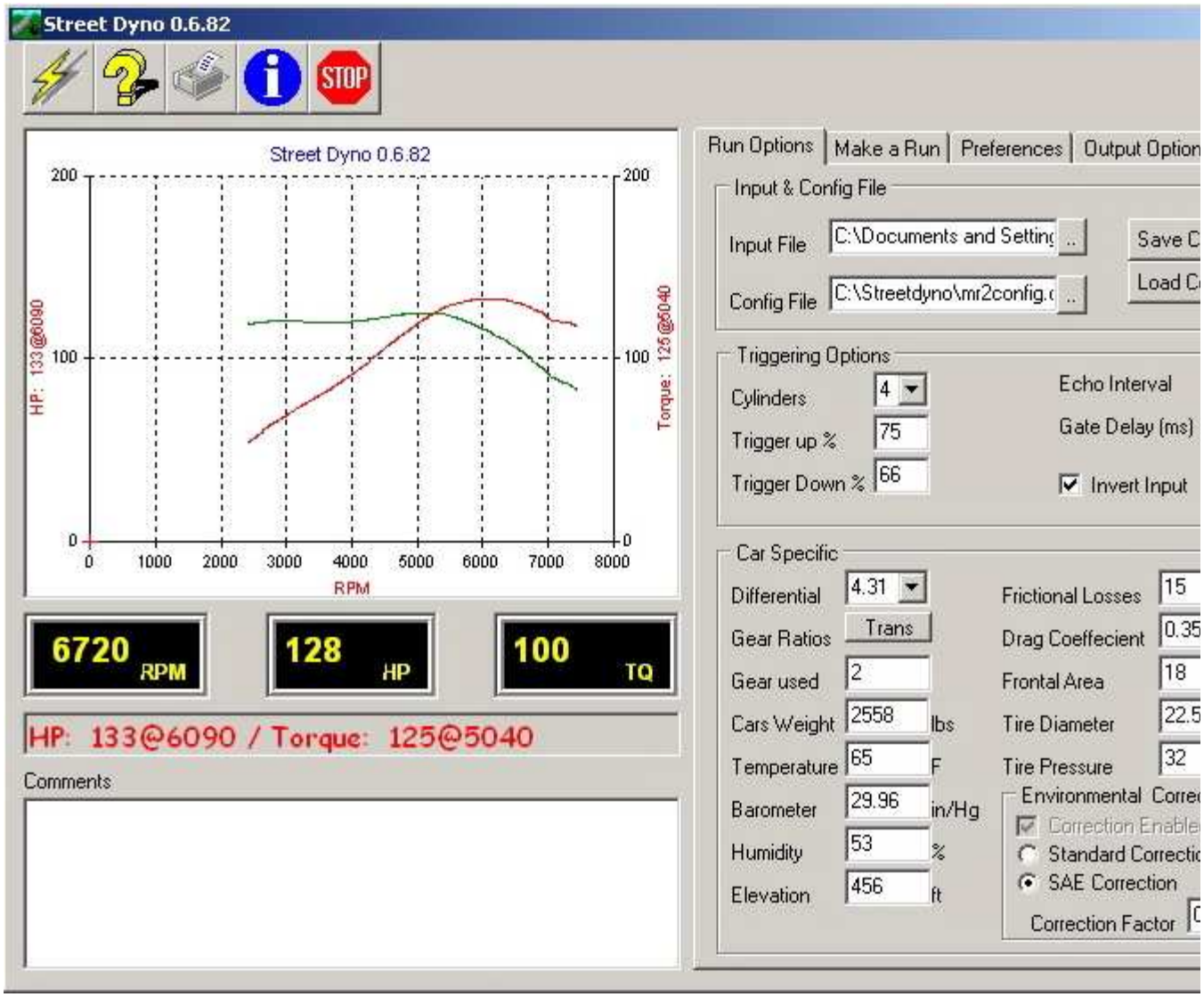
Intake cam advanced 10 degrees, ignition at 5 BTDC: 144hp at 6280, 137ft/lb at 4150

I tried disconnecting the TVIS system so that it would remain open all the time. Strangely, this helped reduce detonation, but it also definitely reduced torque below the 4400 RPM crossover point.



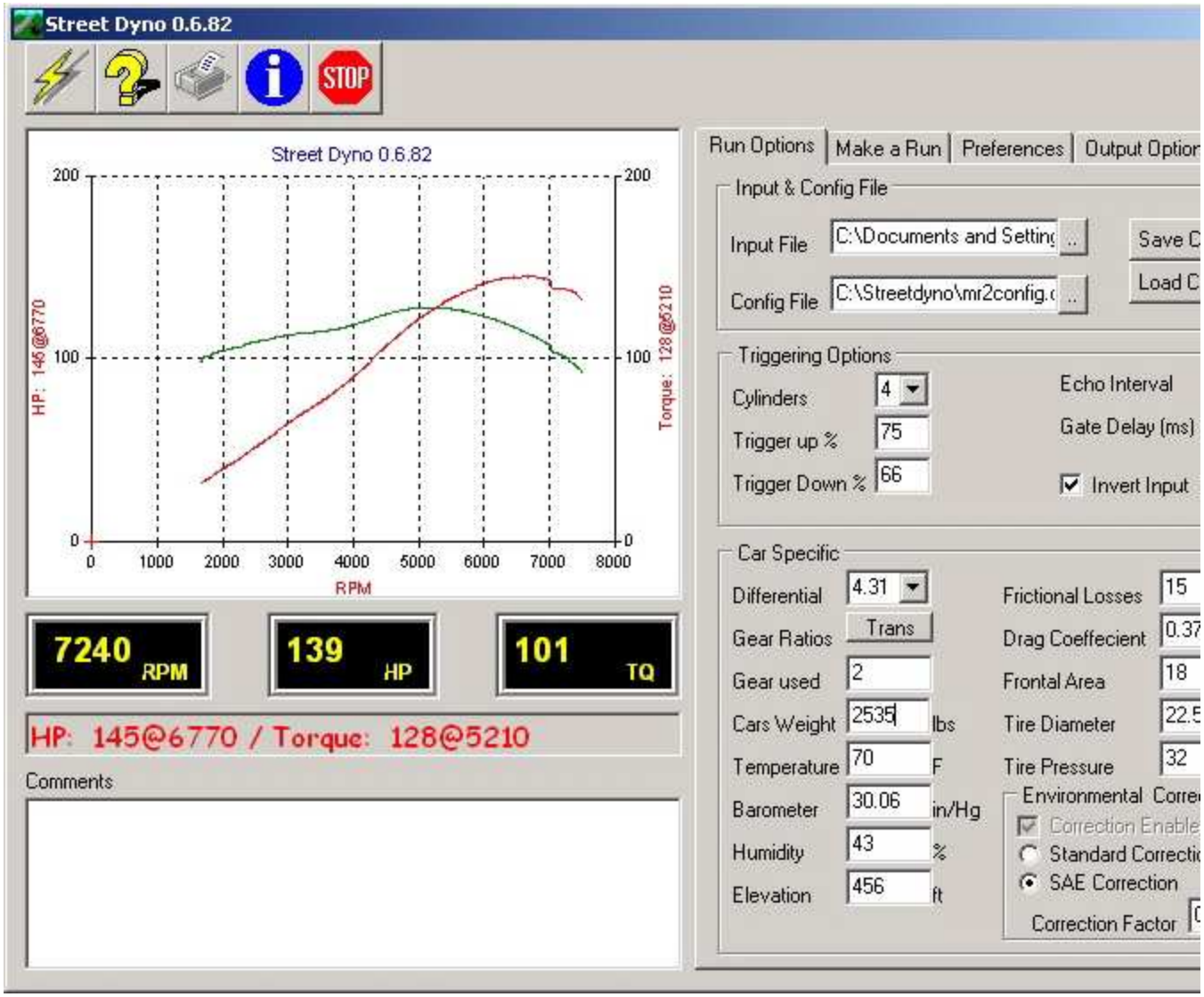
TVIS disconnected: 144hp at 6500, 134ft/lb at 4700

Oddly, adjusting the exhaust cam two degrees in either direction seemed to do nearly nothing, so I left it alone. I think the stock cams were giving me about all they had. It was time to try the Web-Cam 577 cams that I'd had on the shelf for so long. Rumor was that the 4A-GE really preferred a larger intake cam than exhaust, so I tried just the intake cam at first. While I had everything apart I also added degree markings to the homemade adjustable cam gears (thank you Stan Lee!) and reset both cams to their OEM positions. I played hell trying to get the thing to start and run decently because I couldn't seem to get the distributor properly positioned. I could get it to 10 degrees BTDC, but not back to 5 BTDC where it had been. After fighting that in the dark for too long I gave up and accepted 10 degrees ignition timing. The results were immediately disappointing; though it sounded awesome when the TVIS system opened up, it made noticeably less power.



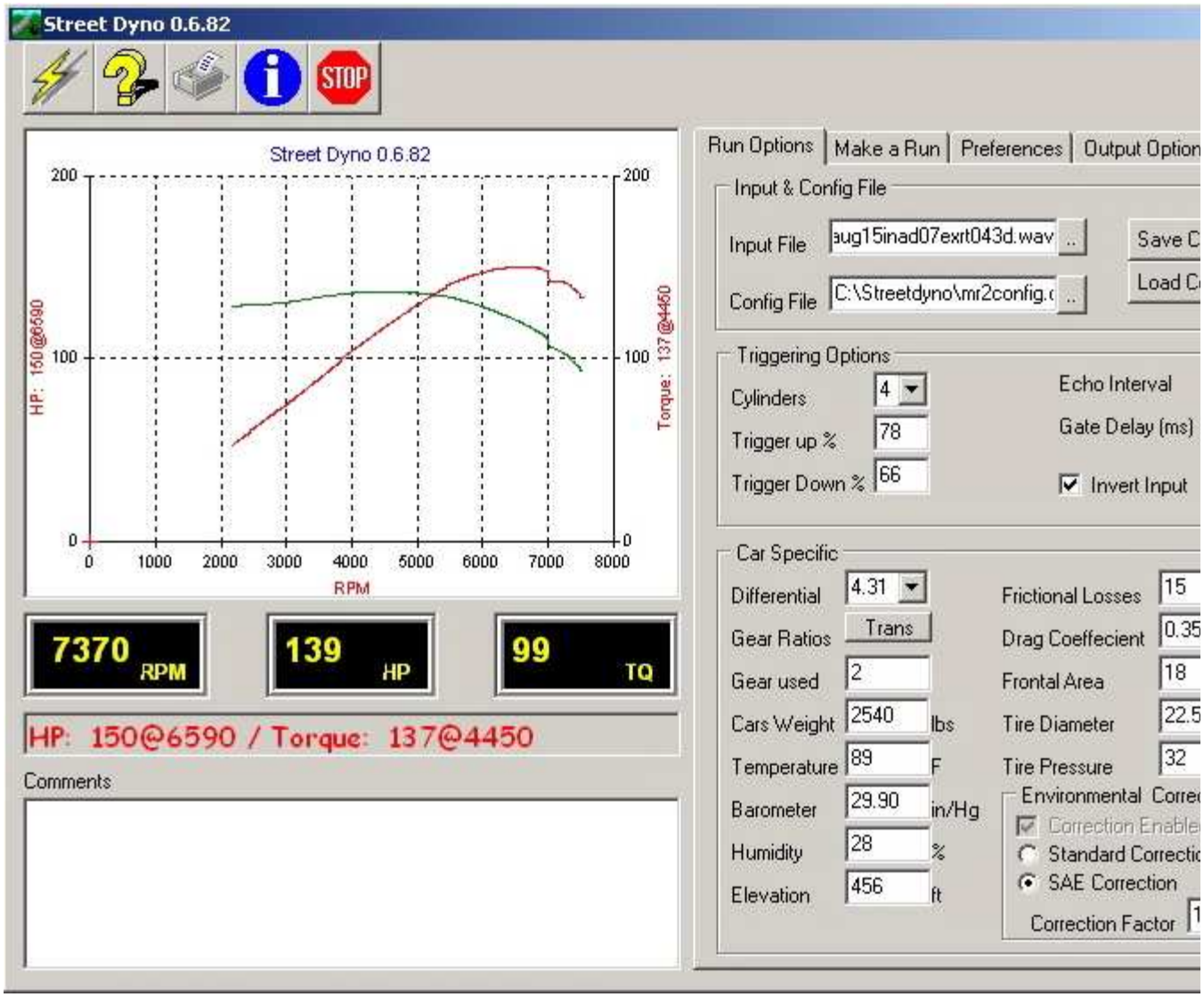
Web intake cam, stock exhaust cam, ignition 10 BTDC: 133hp at 6090, 125ft/lb at 5040

This was really unexpected. I thought that cam was going to set the world on fire. When things get really dumb I usually go through and double-check all the basics. In this case I wanted to be positive that the TDC mark on the crank pulley really meant TDC, so I checked it against piston position using a dial indicator down the spark plug hole. Turns out it didn't match up. Either it had slipped (it is a rubberized harmonic damper) or I had miscalculated it, but it was off by five degrees! I remarked TDC on the pulley and reset the cams, which had both been advanced by five cam degrees, and put the ignition timing back to true 10 degrees BTDC. TVIS was still disabled.



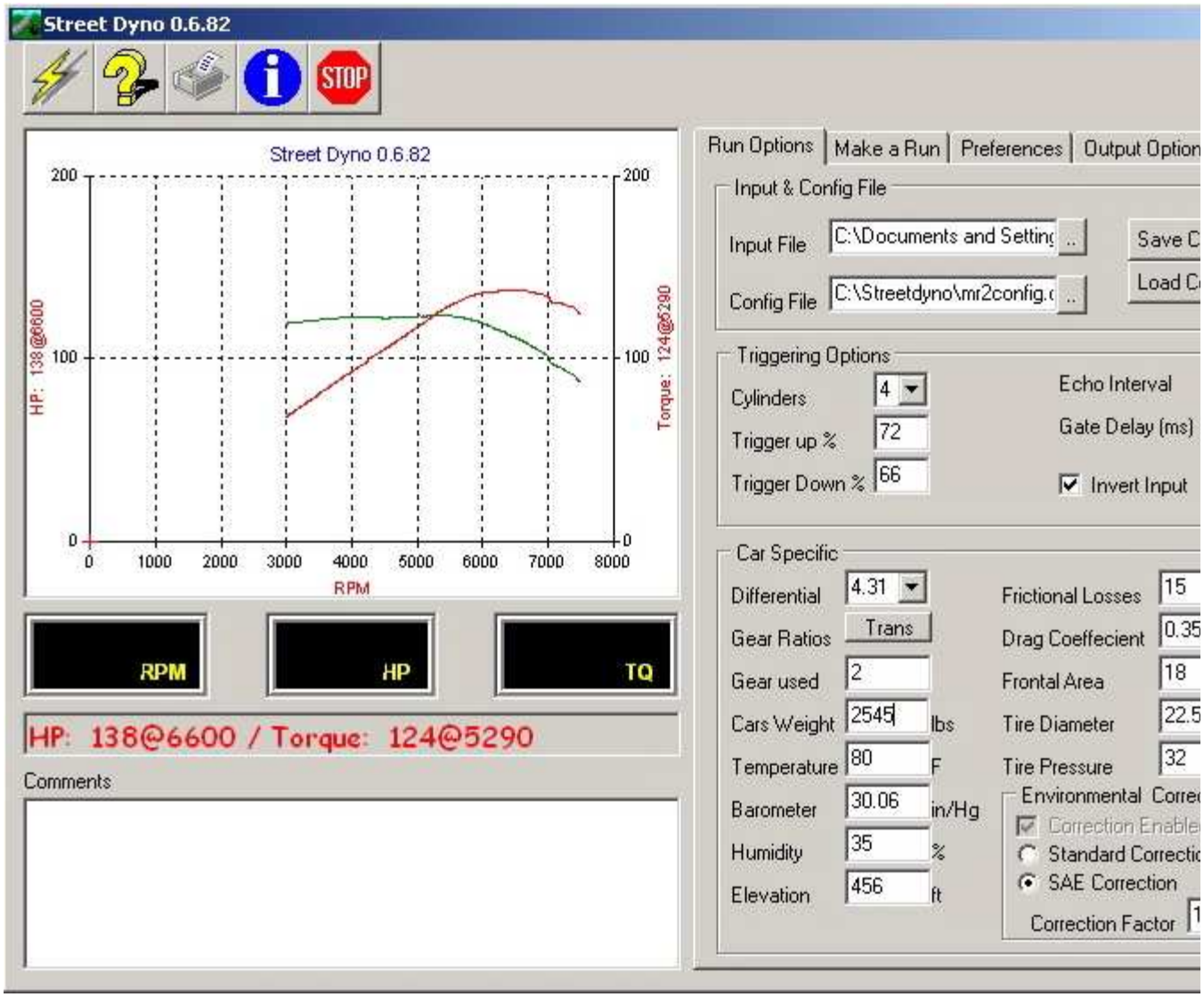
Web intake cam & stock exhaust cam set to OEM positions: 145hp at 6770, 128ft/lb at 5210

So we hadn't gained much, but we hadn't lost anything, either. I reconnected TVIS, which fattened up the torque curve below the peak, and then continued to mess with cam timing, advancing the intake in steps to seven degrees, and then retarding the exhaust cam four degrees.



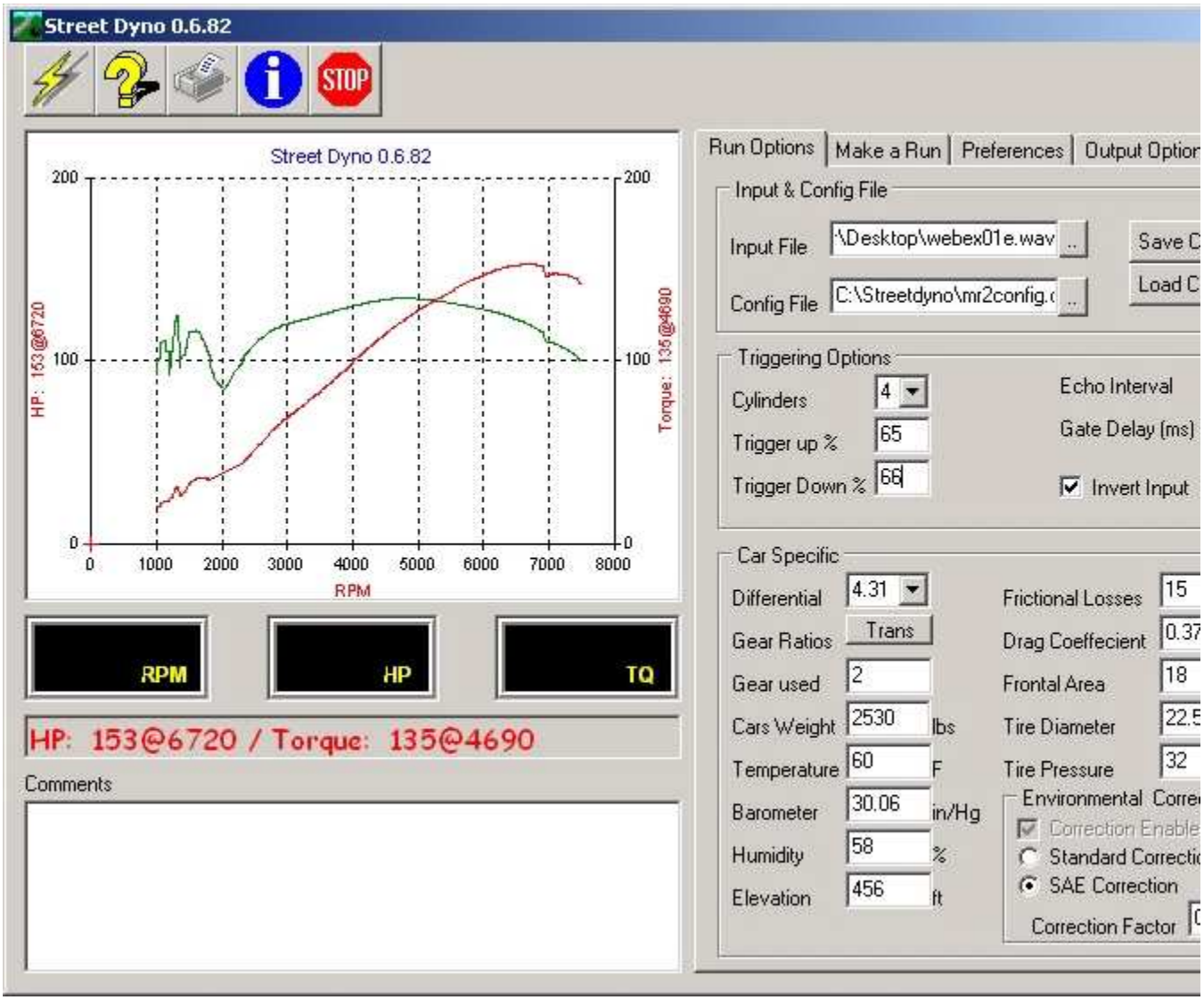
Web intake advanced seven cam degrees, stock exhaust cam retarded four degrees: 150hp at 6590, 137ft/lb at 4450

The horsepower curves were rising steadily until about 5500 RPM and then rose less quickly to the peak. I wondered if there was something restricting the airflow through the engine so I replaced the perforated glasspack resonator with a straight 2 ¼" pipe. I guess the engine liked the resonator, since it gained only one horsepower but lost 2-3 ft/lb of torque between 4000 and 5000 RPM. I think it must be the volume of the resonator case that provides the benefit. The horsepower curve still slowed its rise at 5500. The resonator was replaced for the remainder of the tests. Further fiddling with cam timing created only minor changes in the numbers so I decided to do something totally pointless and see how much power the air conditioner draws!



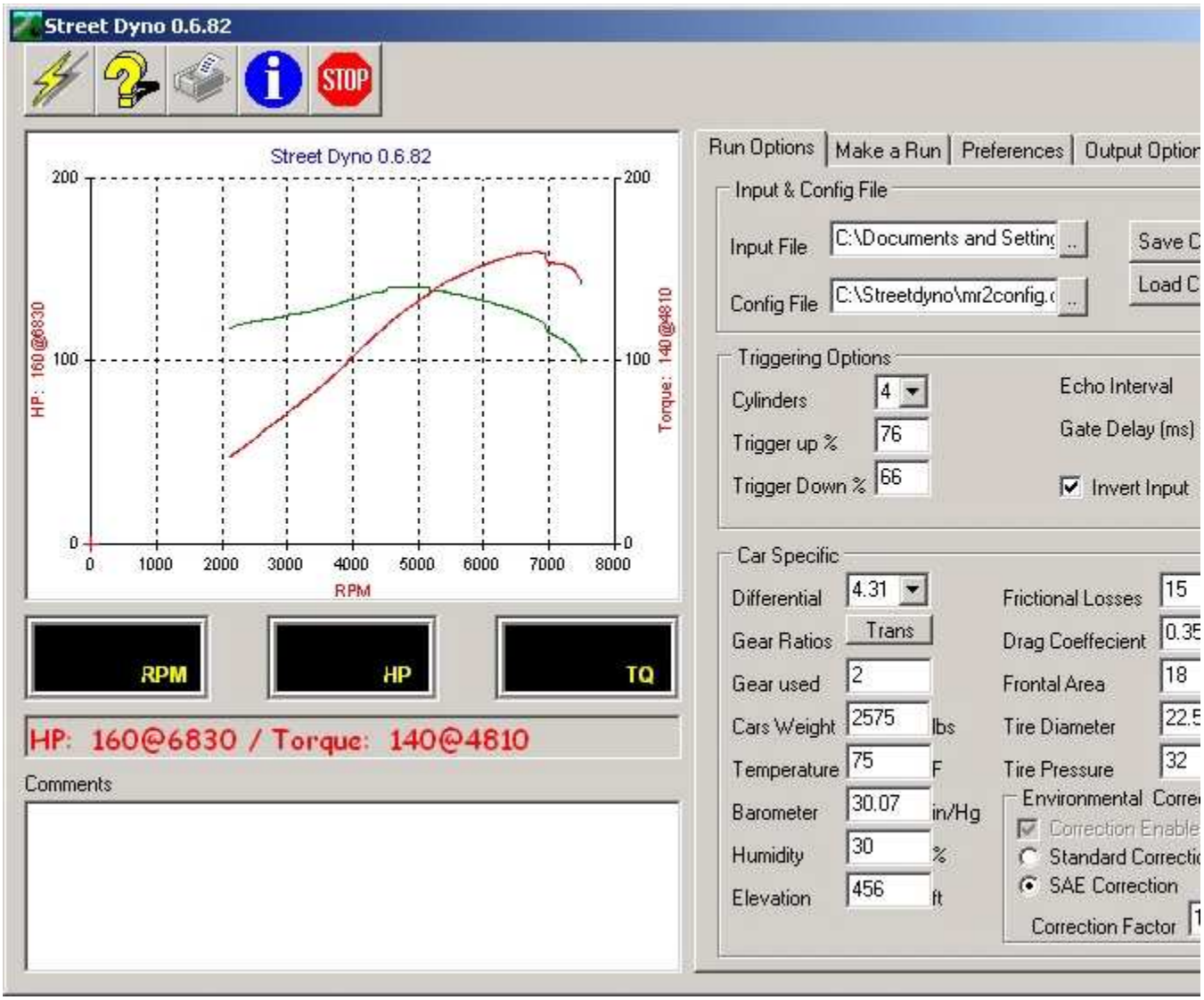
As above but with air conditioning engaged: 138hp at 6600, 124 ft/lb at 5290

Next I tried the Web exhaust cam. It installed easily enough and I left the cam timing where it had been. The car ran pretty badly at low speeds, idled roughly, tried to stall when coming to a stop, and was generally no fun to drive around town. I made only one run as it was very late when I finished, netting a disappointing set of numbers.



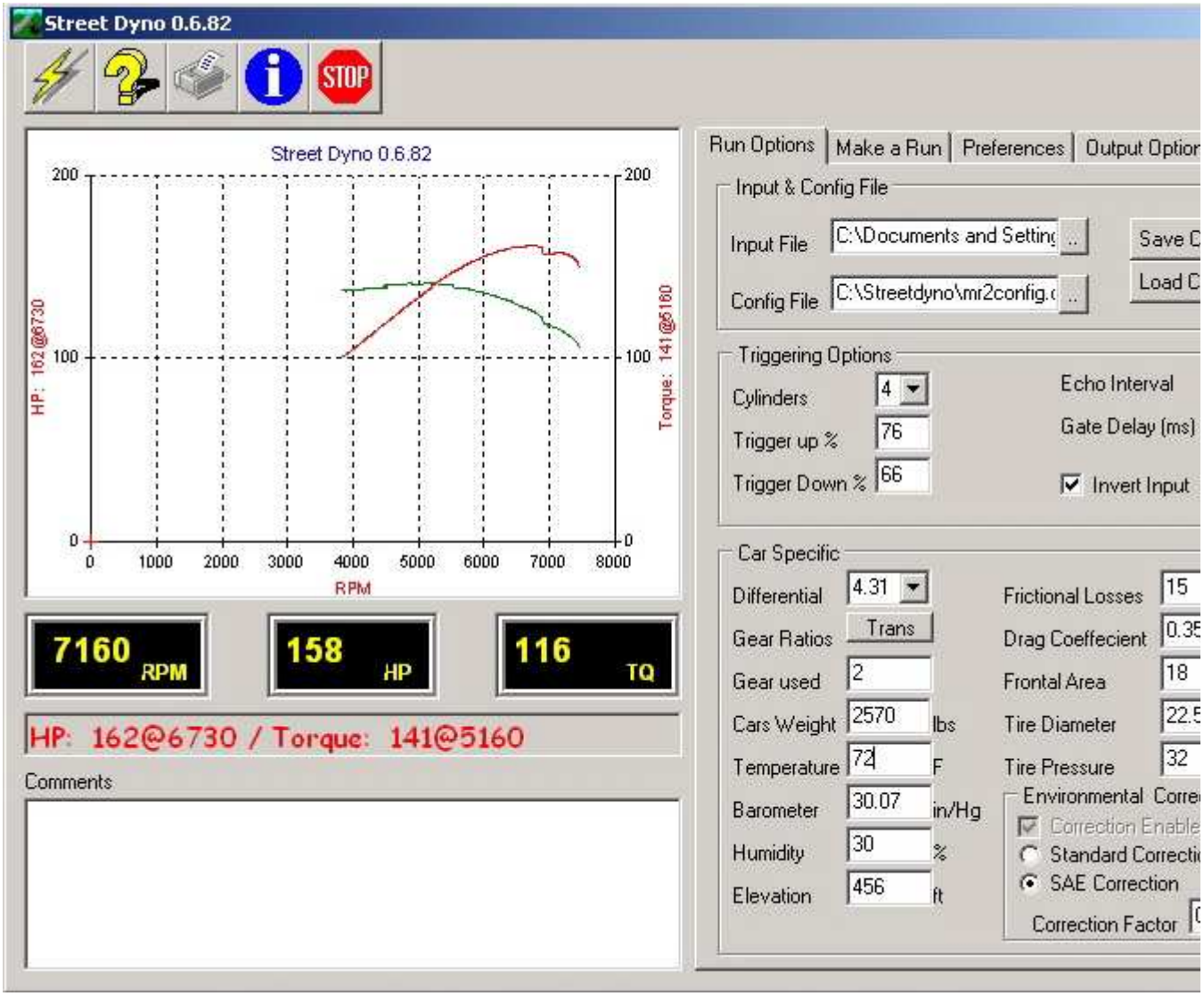
Web intake cam advanced 8 degrees, Web exhaust cam retarded 4 degrees: 153hp at 6720, 135ft/lb at 4690

Later that week I retested the car in the exact same configuration and proved the value of never relying on just one run. Whether the car was just not hot enough or I hit a headwind or whatever, that first run didn't make near the power it did when retested:



Web intake cam advanced 8 degrees, Web exhaust cam retarded 4 degrees, retest: 160hp at 6830, 140ft/lb at 4810

If these numbers can be believed, I finally made my original goal of 160hp! Naturally there was more to be gained by further fiddling, and after several runs it seems to be happiest with the intake cam eight degrees advanced and the exhaust cam straight up. It's now behaving much better than it was, though it still idles a little roughly and is happier above 2000 RPM. I can still use the air conditioner without any trouble.



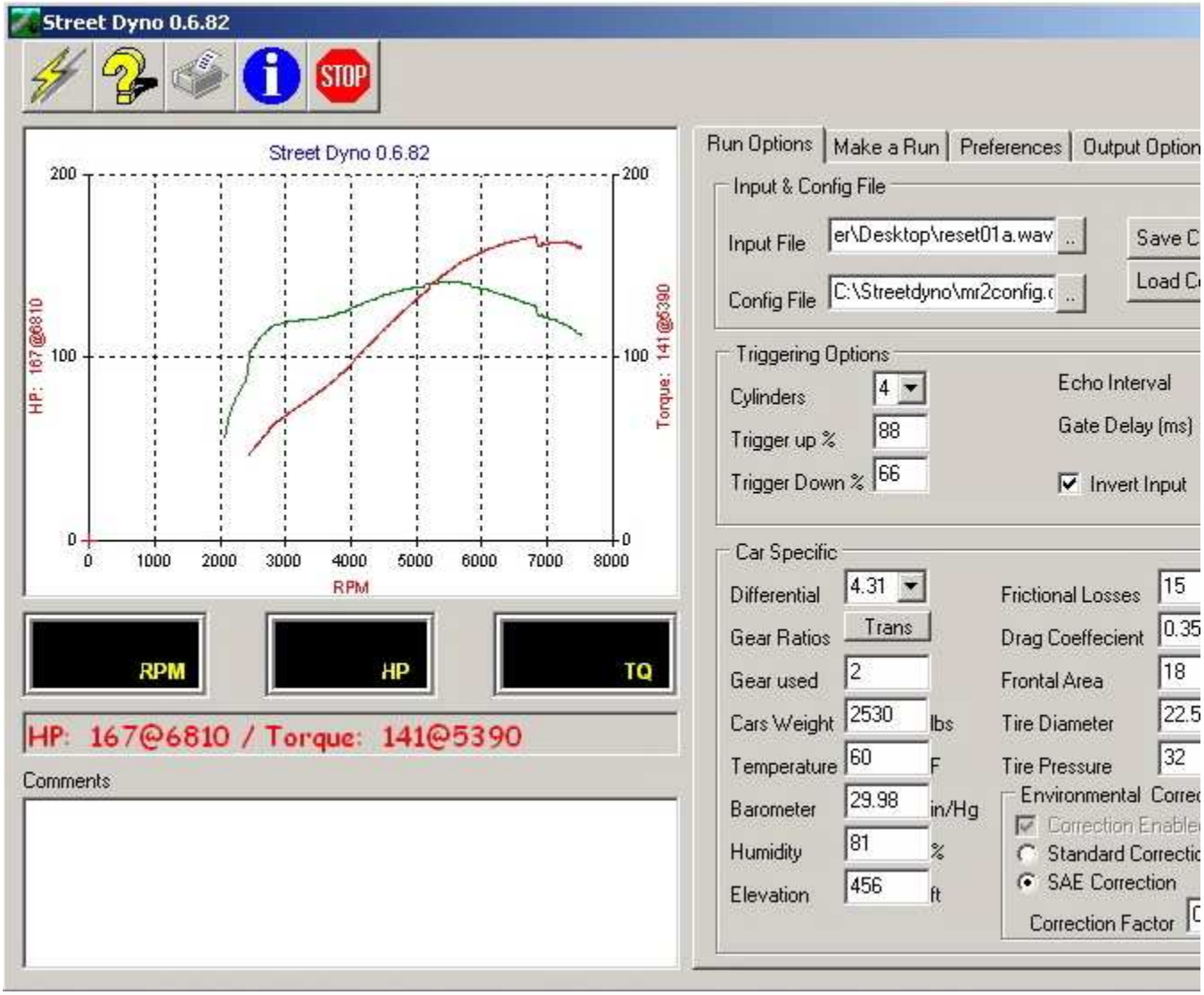
Web intake cam advanced 8 degrees, Web exhaust cam straight up: 162hp at 6730, 141ft/lb at 5160

So there it is, twenty horsepower more than I started with. I've realized that cam timing alone will not eliminate the part-throttle detonation, so I've decided to go with a Megasquirt programmable ECU. I'm also going to try a larger header (the modified silvertop 20V unit only has 1 3/8" primary tubes). I think there are at least ten more horsepower and maybe even more in this engine without going to ITBs or spinning it past 7500. In fact, I found a bunch more in an intake manifold swap...

I wanted to try a different intake manifold because the stock manifold is rumored to be at its limit at this power level. People say nice things about the smallport intake manifold, and I happened to have one sitting around. But everybody knows a smallport manifold doesn't fit a bigport head. It will bolt on, but the difference between the port widths is so great that the flange on the smallport manifold doesn't even cover the big intake port. Besides which, the smallport manifold is way too small too feed the bigport head anyway, right? Well, maybe. I made an adapter plate of

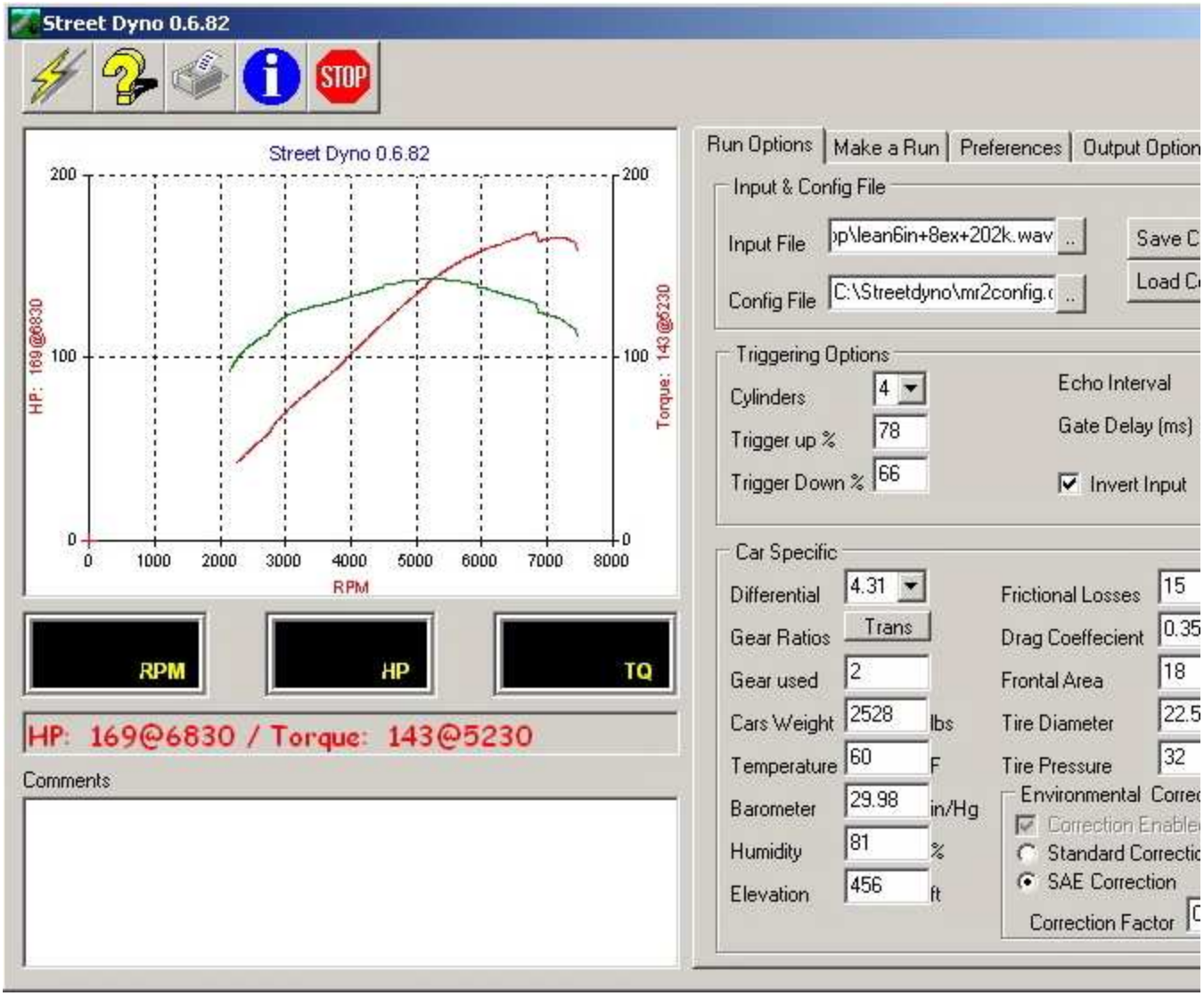
1/8" thick aluminum to cover the gap between the manifold and the head, and then ported the manifold as close to the size and shape of the port in the head as I could. You can see all the changes made to make the manifold work and see why it's a better match than you'd think on the Smallport Intake Manifold Conversion page.

The modified smallport manifold went on without any major drama and the car seemed to run pretty well. I took it out that night after I put it together and it felt great just driving around the neighborhood, so I made a couple of runs to see what effect the manifold had. I never count nighttime runs as official since the headlights are up and that changes the aerodynamics of the car, but still, it showed between five and eight extra horsepower. What the peak numbers don't tell is a substantial drop in torque between 2000 and 5000 rpm. Of course, that's where you do most of your driving, so if this was a normal passenger car I'd call this experiment a failure. But since there is a lot more average power between redline and the RPM you land at when you upshift at redline, I would say this is a worthwhile modification for performance driving or racing.



Smallport intake manifold, ECU reset: 167hp at 6810, 141ft/lb at 5390

The only thing I've done since then is to lean the fuel curve by tightening the spring on the airflow meter and move the exhaust cam just a bit.

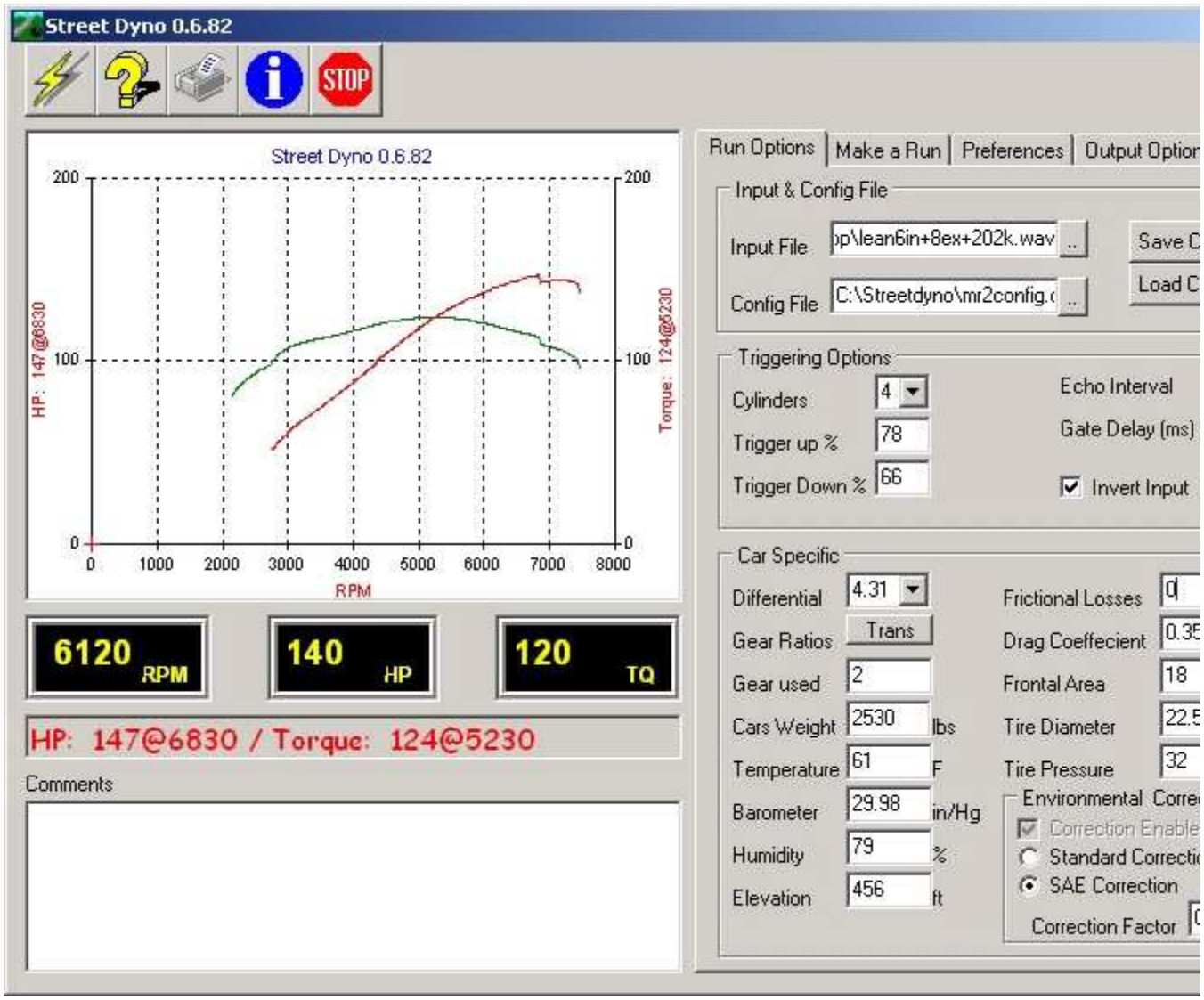


AFM six clicks leaner, exhaust cam advanced two degrees: 169hp at 6830, 143ft/lb at 5230

I think there's more to be had here with further tuning, but I suspect a bigger throttle body and especially a bigger/better header would definately help this engine out. All in all I am very happy with the performance of this combination, but I'm not completely satisfied.

Below is an estimate of the horsepower at the rear wheels. This is the same run as above, but with Streetdyno compensating for 0% friction (drivetrain) loss instead of 15%. Keep in mind that this is for conversation only; until the car sees a real dyno, this is only an estimate of what it should or might put out at the wheels. Still, it's

something to think about, and I'm eager to see how close it actually comes to these numbers.



Estimated rear wheel output: 147hp at 6830, 124 ft/lb at 5230

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