DIY Zoning: Technical FAQ

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Questions

1. Common Facts

1.1. What are DZ primary objectives?

The primary objectives are:

1. Home comfort.
2. Energy cost savings.

In that order.

The secondary objectives are, in no specific order:

- Flexibility;
- Remote accessibility;
- Seamless integration with home automation.

1.2. What's wrong with existing zoning systems?

First of all, they are outrageously expensive. Typical cost per room is anywhere between $600-1300.

They are also not too smart for the price.

Very few systems offer variable airflow control, usual way of operating is known as "bang-bang" - totally open or totally closed damper. The consequences of this are the temperature swing (common for all low to midrange HVAC systems, though), abrupt changes of the airflow and static pressure, and associated noise.

The extensibility of the zoning systems is usually very poor - "advanced" systems that are capable of handling just 2-3 zones are not a rarity.

All of the systems offered on the market are proprietary.

1.3. How DZ is better than commercially available systems?

Before reading further, take a look at what's wrong with existing systems.

Now, here's **why** it's wrong. The existing zoning systems were built by companies that have been on the market for a long time, have established operating procedures, trained personnel, quite possibly they have grown beyond the ability to change. They do stuff a certain way "because we always did it this way". They completely ignore the progress in the embedded systems and still rely on low integration specialized chips to manufacture their controllers, and miss the opportunity to utilize the power that embedded microprosessor based systems offer.

This system, on the other hand, was originally created as a hobby project that was not intended to be run on anything other than a quite powerful workstation, but in the end it turned out that it is SO SIMPLE, it can be run on $100 microprocessor board without any changes to it.

Summarizing the advantages:

- It is infinitely flexible;
- The number of zones is practically unlimited;
- Functionality can be added without adding cost;
- It can work with cheap hardware as well as expensive without any changes;
- It can be remotely controlled;
- It can be remotely diagnosed;
- It is fault tolerant;
- It is cheap as dirt.

1.4. How many zones can the system control?

Short answer: unlimited.

Long answer: it is limited by how many damper controllers you can connect to your computer. If you use the serial controller, the reasonable number is one (or two, if you use the USB controller for 1-Wire® network devices). If the servo controller is stackable, the reasonable practical limit is somewhere between 128 and 256. If the servo controller is a USB device, you can install up to 256 servo controllers (less number of USB hubs), each of them supports 4 to 8 dampers (**Update:** 25 Servo Controller exists and is priced more than reasonably).

1.5. Can the system also be used for gas heating?

Clarification: this question relates to forced air gas heater, also known as a furnace.

Yes, in fact it works even better with gas heating because the heat exchanger takes time to cool down after the gas valve has been closed allowing the gas valve to be cycled to maintain a constant discharge temperature. The controller will prevent the heat exchanger from overheating while the unit safeties will remain in case of a catastrophic failure.

1.6. Can the system also be used for water heating?

Clarification: this question relates to the heater that heats the water in the tank and then sends it to heat the radiators in the rooms.

Tough question.

From the technical standpoint, there's nothing preventing the system to do so - all you have to do is to use the computer controlled valves and a different driver for the heater.

From the safety standpoint, the consequences of the water heater system gone amok are far greater than for the forced air system - anyone in vicinity of the exploding hot water pipe is guaranteed to have at least severe burns.

> **Note:**
> Update: starting about December 2003, DZ is, in fact, being successfully used to control the water boiler.

1.7. Is it possible to have a wall controller?

Short answer: yes.

Long anwer: it depends on how much you are willing to spend. A single wall controller for all the zones will cost about $150-200, which is comparable or less than "professionally istalled" one, a simple room controller will cost much less, but it was not spec'd yet.

Ask yourself a question: do you **really** need a wall controller? How often do you use your TV's control panel? All of them now come with remotes...

Update (2009/11): Wall controller will be most probably abandoned in favor of Android based application.

1.8. What's wrong with making the graphs visible to all the Internet?

Call me paranoid, but this can be used by someone with malicious intent to figure out your schedule, whether you're home or not, and even what room people are in at any given moment of time.

Consequently, this makes break-in planning easier (oh, just google up twitter burglary already).

A way to eliminate this issue is to provide delayed graphs - change the `--end ${date}` parameter to `rrdgraph` to a reasonable value. And make the current graphs password protected.

2. HVAC

2.1. What happens with excess static pressure?

It is taken care of. The system balances the airflow in such a way that no less than X% of dampers are open at the same time. Preliminary modeling shows that X should be no more than 30-40, otherwise there will be loss of quality control. This means that the ductwork should be capable of supporting proper airflow even with only 30-40% dampers open. This is unavoidable.

2.2. Does the system need bypass dampers?

Short answer: no.

Long answer: the system takes care of excess static pressure in a different way.

Longer answer: here.

2.3. Are $10 dampers better than $200 ones?

The damper in question is here.

Short answer: yes and no.

Long answer: of course, they are better from cost efficiency standpoint. However, "what you get is what you paid for", to some extent. The register based dampers are not as good as (allegedly) precision engineered airflow dampers, however, good registers may do a better job than "entry level" dampers. Another disadvantage is that the registers are almost guaranteed to create an air velocity loss because they are not placed at strategic locations, as the dampers are. This leads to lesser efficiency.

However, exactly as there are people who can afford Huyndai and can't afford BMW, there are people who can afford $10 dampers and can't afford $200 ones. The poor people suffer from heat and cold exactly the same way as the rich. If you can't afford $200, $10 will definitely make your life easier.

2.4. What about high temperature differential?

The complete question is "What about high temperature differential across the indoor coil due to low airflow"?

With single stage A/C, there is a limited ability to protect the compressor from high tempereture differential at least by shutting off the compressor while letting the fan run. This is a theoretical answer, from the practical standpoint it is yet to be seen how high the temperature difference will get when the airflow is restricted in a way it is being done by this system.

The best answer to this question is: use multistage compressor coupled with variable speed fan (see Homeowner's FAQs). This way, fine grained control is possible.

3. HVAC: Excess Static Pressure Relief

3.1. Excessive Static Pressure Problem Definition

When the dampers are partially closed, the air pressure inside the duct increases. This leads to increasing so-called "static pressure", and if the indoor fan is not capable of handling the increased static pressure, this results in decreased airflow across the indoor coil and may lead to excessive wind noise from the registers.

Reduction of the airflow, in turn, leads to lower temperature of the indoor coil, because the amount of air moving across it is no longer sufficient to maintain the proper temperature.

This, in turn, will eventually lead to the incomplete evaporation of the refrigerant, which means that the liquid will leave the indoor coil (which it is not supposed to do) and reach the compressor. Usually, the compressors are incapable of handling liquids (with excepsion of "scroll" type compressors), and liquid refrigerant reaching the compressor will cause "slugging", which will eventually damage or destroy the compressor.

On the other hand, dropping temperature of the indoor coil will eventually lead to the freezing of the water vapor contained in the air on the coil surface, which will further degrade the heat transfer capability and reduce the airflow, thus triggering the domino effect.

3.2. Ways to solve the problem

Note:

Credit for this section goes to **T. Shannon Gilvary**. The materials on this page are a digest from "Excessive static pressure relief" discussion thread on DIY-Zoning-general mailing list. The complete thread may be found here.

There is no cure from all diseases, and the solutions to the problem of relieving excess static pressure relief range from simple and workable, but not without pitfalls, to significantly more complicated and somewhat more expensive.

#1 Traditional (hardware only)

So-called "bypass damper" is installed. A bypass damper routes air from the supply ductwork back to the return so the air handling unit gets a constant flow of air, but the ductwork after the bypass sees a constant static pressure.

Pros: Simple, relatively inexpensive, allows additional humidity control. Avoids overshooting problems since cooled air is not dumped in areas where it is not needed.

Cons: Unmanageable, prone to mechanical failures. Improperly tuned bypass damper will either not serve the purpose (if it is too tight), or waste the energy (if it is too loose). Doesn't protect the unit from freezing or slugging - there's no feedback loop. Requires modification of ductwork.

#2 Simplest, least expensive (software only)

The threshold is set for the minimum total opening of the dampers. As soon as the open area of all the dampers falls below this threshold, the designated "dump zones" will start opening the dampers in such a way that the open area is no less than threshold.

Initital modeling shows that the threshold should be set around 30-40%. Anything less, and the static pressure increases unacceptably. Anything more, balancing quality degrades.

Pros: Simple (no hardware required at all), inexpensive (zero dollars zero cents), configurable.

Cons: Careful tuning required. Doesn't protect the unit - there's no feedback loop. This and following solutions will share the common problem: dump zones will be prone to overshooting (overcooling when cooling and overheating when heating).

#3 A little bit more expensive (software and hardware here and below)

Pressure sensors are installed on HVAC unit return and supply. As the static pressure increases, #2 algorithm is applied to control the dampers.

Note:

This solution allows to adequately solve the problem of *controlling the static pressure*, but there's a problem of preventing the coil freeze and slugging the compressor which is yet to be solved.

Pros: Couple of sensors are probably less expensive than the bypass damper, this solution has all the advantages of the software. Assumption is removed from the picture - the real static pressure is measured and controlled. No ductwork modification involved. Freezing and slugging is less likely but not completely eliminated.

Cons: Still no temperature feedback from the unit.

#4 Somewhat more expensive

In addition to pressure sensors from #3, temperature sensors are installed on HVAC unit return and supply. Watching the temperature trends will allow to reliably determine the unit condition and take corrective action.

Pros: Unit condition can be determined with high probability, adding fault tolerance.

Cons: Even though the trends can be analyzed and decision made, those temperature readings do not guarantee 100% that the coil will not freeze.

Note:

It is also possible to install temperature sensors not for the air stream across indoor coil, but for the refrigerant flow - one sensor immediately before the coil, the other after. It is not quite clear how to analyze the temperature patterns yet (they turned out to be quite bizarre), and how to correlate temperature readings against saturation temperature (requires further investigation), but one thing is certain: if the outgoing refrigerant temperature is getting to a water freezing point, something has to be done.

#5 Even more expensive

Here, we start intruding into the unit itself. In addition for supply/return pressure and temperature sensors from #4, additional temperature sensor is installed on the indoor coil.

Pros: The coil will not freeze.

Cons: It is still possible to slug the compressor. Indoor coil is almost always not easily accessible. Though relatively simple, this requires the HVAC unit modification, which may void your warranty, if you're not careful enough.

#6 Yet more expensive

In addition to sensors from #5, the pressure and temperature sensors are installed on the suction line. Corrective action is taken when the suction line temperature is getting close to the saturation temperature for the given pressure.

The suction line is not easily accessible in a package unit. Installing a pressure sensor on the suction line is a procedure that can be performed only by a HVAC certified technician. Kids, don't do this at home. Warranty is most probably bye-bye. Check with the manufactuer of your unit.

Pros: Almost bulletproof solution.

Cons: Careful tuning is required - the saturation temperature/pressure chart will be different for different refrigerants. It's not quite clear if this is worth the trouble, possibly, it's an overkill. Remains to be seen.

#7 The ultimate solution

Combining the methods of #6 with the bypass damper from #1, the static pressure can be maintained without over cooling any areas or wasting energy. The compressor can be controlled to maintain a constant air temperature without worry of freeze-up or slugging.

Pros: The best protection and static pressure control.

Cons: Requires ductwork modification, installation of several sensors, some of them expensive, and may be overkill.

3.3. Best Protection for the Money

Of course, "best" is a subjective term and should be taken with a grain of salt. If overshooting some areas is not a problem, then option #5 will work for most people. If you would rather avoid overshooting, then adding a bypass damper to option #5 is the best bet. Of course, if money is no object, then by all means, go for #7. Consider the cost of replacing a condensing unit, energy costs, and how much unit modification you want to get into when making your decision.

3.4. Price considerations

Pressure sensors are significantly more expensive than temperature sensors, so it is possible to skip option #3 and install the temperature sensors per options #4 and #5. The static pressure will go unchecked, but quite predictable, and will not matter much because the main problem is actually preventing the coil freeze and slugging the compressor. The temperature sensor is about $3, so we're looking at total of $12 plus cost of cable or wireless transceivers.

4. Hardware Installation

4.1. Is it possible to run wires within ducts?

Short answer: check your local building codes.

Long answer: possibly. In some places, you are allowed to use "plenum rated" wiring inside your ducts. The difference between plenum and non-plenum cable is that the latter produces a lot of smoke and toxic fumes while burning, while the former does not.

> **Warning:**
> Failure to comply with your local building codes will create problems upon selling the house, or a building inspector visit.

4.2. Is it possible to make this system wireless?

Short answer: yes.

Long answer: the cost may be prohibitive. Currently, some products are available on the market that allow the drop-in replacement (for example, PointSix wireless temperature sensors), but the cost is very high - the abovementioned sensor retails for about $80, vs. $3 or so for the 1-Wire® sensor. The price for the sensors starts to be more or less reasonable in quantities of well over a million, which, of course, is not something you'd be interested in. The only hope is that the wireless hardware is getting more commonplace and therefore cheaper, so with some luck this system will go wireless sometime soon. By the way, if you're reading this and know about cheap[er] solution, your input would be greatly appreciated.

Another aspect of it is the power delivery. The sensors will feel quite OK and probably work for a few years with no problems (especially keeping in mind that some models, like the one above, support the "standby" mode and don't have to broadcast the readins more often than once in 10-20 seconds). The servos, however, are power hungry, as well as their receivers. It is, of course, possible to pack them with the big batteries, but I'm afraid they'll have to be replaced quite often anyway.

4.3. Isn't it too complicated to use R/C servos for dampers?

As a matter of fact, no.

Despite apparent complexity, the R/C (short for **R**adio **C**ontrolled) servos are amazingly simple and reliable in operation. They are ***designed*** to be abused, and stand up pretty well. So, *reliability* is one reason to use them.

Another argument is *flexibility*. Standard HVAC dampers are usually open/close only, with very few exceptions (those are called *modulating* dampers). Open/close dampers are quite noisy mechanically (can make you jump in a quiet room), and contribute to increased wind noise - it's quite possible to hear the ductwork resonance frequencies change as those dampers open and close. Combined with increased airflow when some zones are completely shut off, this may create some serious wind noise problems. Final argument, modulating dampers can provide better temperature control than open/close ones.

With R/C servos, I can do whatever I want to the damper position. In particular, at this moment "crawling" position changes are implemented - a damper changes its position in small increments without any noise whatsoever. Transition from completely closed to completely open position completes in about 10-15 seconds, which is acceptable from airflow control standpoint.

4.4. Do these dampers return to open position on power failure?

No.

However, think about it for a second: what is going to lose power first - multikilowatt consuming HVAC unit, or a servo that can work off the 6V battery (or even USB bus)? And what do you care if the damper is open or not when the HVAC is off?

This kind of behavior is, of course, a nice safety net, however, with DZ's paranoid treatment of failure conditions it's simply an overkill.

A complete answer to this question would be: if you are planning to run DZ, it would be a good idea to provide the computer it runs on with an uninterruptible power supply anyway, so the point becomes kind of moot.

4.5. Is it possible to use dampers other than based on R/C servos?

Yes.

Any kind of dampers (as well as other peripherals) may be used with DZ, as long as the drivers exist.

4.6. Is it possible to use servos to control dampers instead of wall registers?

Yes.

The procedure is essentially the same - install the servo mount and provide a linkage from the servo horn to the damper control lever. More detailed answer is provided here.

4.7. Where do I install temperature sensors?

I got away with positioning the sensors next to the light switches - in US, they're at about 130cm (approximately 50") high.

Generally, you'd want them to be approximately at the height that matters to the occupants - lower in the bedrooms (and possibly family room, where people often sit), higher in the work zone of the kitchen.

Avoid installing the sensors where they would be affected by the airflow from supply ducts - this will cause short-cycling (and all problems associated with it) and uneven temperature distribution.

4.8. How close to the wall can I mount a sensor before the responsiveness and accuracy suffer?

My sensors are sticking out about 5cm (2") on twisted pair, feeling just fine. Enclosing the sensors in anything increases the temperature inertia, but there are several factors that may make this irrelevant: the PID controller I and D components may be increased to offset the increased temperature inertia of the sensor. However, a noise filter must be implemented, because 1-Wire sensors (and, I suspect, any kind of sensors) have limited precision, and D component may go nuts just because of the noise. Simple integrator may work if its time span is matched to the actual inertia of the sensor and enclosure.

4.9. Can I use existing thermostat as a sensor?

Theoretically, yes. Physical thermostat will provide the same functionality as a virtual thermostat. However, there are drawbacks:

- You will depend on the quality of the existing thermostat. Good thermostats are expensive, inexpensive thermostats are not good. Good thermostats usually come (for the price) with the features that DZ already implements (for free), so there's no gain.
- You will not be able to utilize advanced features of DZ that require access to the "virtual thermostat API", in particular, fine tuned balancing and zone resonance.

4.10. 1-Wire sensors look ugly, can I use something nicer?

Sure, but it'll cost ya. The list will be long, so here's just one example of how a sensor may look like: Decora-Style Analog Temperature Sensor from SmartHome.

You can use any sensor as long as you have (or write) a driver for it.

4.11. There are too many choices for 1-Wire sensors, which one should I really pick?

Doesn't really matter. The answer to this question is determined by price and availability, rather than technical features. The sooner you want it, the more you will have to pay. Dallas lead times may be several weeks, if not months - last time I checked.

5. Software Installation

5.1. What hardware platforms are supported?

Basically, any platform that is able to run JVM will do.

Oter than that, one of the Arduino family is certainly not a bad choice - but existing code base will not work there.

5.2. What software platforms are supported?

Besides native Java platforms (such as TINI, see above), DZ can run on any UNIX that can run JDK 1.4 and up. Best tested on RedHat Linux, currently being developed on Mandrake Linux, also known to work on FreeBSD.

5.3. Can I compile DZ under Windows?

Short answer: yes.

Long answer:

Warning:

Don't be discouraged, though - it is definitely possible, it's just that I'm not interested in making this application work under Windows at the moment - and the sanity of the person who would trust their very expensive HVAC hardware to Windows must be questioned. Data acquisition only setup is exempted, though - there's no harm in that.

Java subset builds without hassle with Maven. For the rest, start with Cygwin.

5.4. Can I run DZ on Mac?

It had been run on Mac (not by me), until the hardware died of unnatural causes.

5.5. How old a computer can be to still run DZ?

As of 2009/11, DZ3 runs on Athlon XP 2000+ with 1.5G RAM built in late 2002, along with a file server for af few terabytes of disks, mail server, Squeezebox server, all the daemons, and plus some other things.

In other words, *pretty* old.

5.6. DAC and CORE running on different boxes don't see each other, why?

Modern distributions come with pretty tight security enabled by default. In order for DZ modules to see each other, the following ports must be enabled on the firewall:

- 5000/tcp - to allow the CORE to connect to DAC sensor broadcast channel;
- 5001/udp - to allow DAC sensor autoconfiguration broadcast;
- 5002/tcp - to allow the CORE to connect to DAC switch control channel (you don't need this if you plan to use just the DAC);
- 5003/udp - to allow DAC switch autoconfiguration broadcast (you don't need this if you plan to use just the DAC);
- 3639/udp - to allow xAP broadcast;
- 3865/udp - to allow xPL broadcast.

In addition to these, some additional ports may need to be opened as the set of protocol supported by DZ grows - keep watching this page.