>> Sally: Hey Dude, how are you?

>> Dude: I'm not doing too well.

I'm trying to figure which device to use to turn off the gas-o-matic module and stop Buddy from growing too big.

But I don't know how to choose!

>> Sally: Hmm, well choosing the right device for your system can be pretty hard.

Why don't we work on this together?

>> Dude: That would be great.

I am just going around in circles here.

>> Sally: Well I'd suggest that you use a digital device to turn off the gas-o-matic module when Buddy got to a certain size.

>> Dude: What's that?

>> Sally: Well let's start with the basics, all digital devices have inputs and outputs that are always in one of two states: either ON or OFF.

People who work with electrical devices sometimes call the two states HIGH and LOW because of the high or low voltages that the devices receive or produce.

Other people think of the two states as true/false or as the numbers 1 and 0.

It really doesn't matter.

What's important for us is that if you hook up the output of a digital device to the gas-o-matic, when the device produces a high signal, Buddy will inflate.

When the device produces a low signal, Buddy will stop inflating and he'll just stay the same size for a while.

>> Dude: That's cool but why make just two states?

Wouldn't it be cooler to make buddy get bigger really fast at first and then slowed down when he's close to full size?

I really don't want to see him growing out of control like before.

Couldn't we build an even more interesting system from devices with more states, like three or even ten?

>> Sally: Those are all really interesting ideas but here's why two states makes the most sense.

Let's imagine that you're measuring the output signal from your digital device over time.

Depending on what the input to the digital device is, the output will switch between its two possible states ON and OFF.

But of course, this drawing is actually a bit misleading.

See all digital devices, whether they are genetic devices or electrical devices, never produce a signal that is perfectly ON or perfectly OFF like I've drawn here.

There are always some minor fluctuations in the signal.

These fluctuations aren't real changes in state of course.

But sometimes, if the fluctuations are too big, then they might tell the gas-o-matic to switch on when you really want it off.

>> Dude: Oh no.

I definitely don't want that.

It took forever to clean up the lab last time that happened.

So the reason we limit the devices to two states is because they work better when there's noise?

>> Sally: Exactly!

>> Dude: And you think Buddy's growth is noisy?

>> Sally: Definitely!

He changes a little just when he breathes.

And he can grow and shrink a lot depending on how much food he has and what's around him.

And sometimes I think he changes size just to show off...

>> Dude: So it sounds like digital devices are the way to go!

It will tell the gas-o-matic device to turn on if Buddy's really growing and turn off if he's full size, but ignore those in between size fluctuations he likes to make...but how big are the fluctuations that the device will ignore?

How does it know?

>> Sally: Well the device only knows what we tell it, and we can split up ON and OFF the way we choose.

>> Dude: OK then...I'll put the ON/OFF border here!

>> Sally: Dude, weren't you listening!

If the signal is somewhere near this boundary and noisy, then the device will from switch ON to OFF or OFF to ON when you don't want it to.

Here's what we can do.

Let's call just this small part the "valid" signals and leave all this in between as "invalid" signals.

That way the device won't confuse ON signal values with OFF signal values so easily.

>> Dude: Aw Sally.

Maybe I'm not getting this at all.

It looks like you just put in two boundaries and now you've got twice as much trouble.

What's to stop the noise from switching between valid and invalid signals here AND here?

>> Sally: Dude, I actually think you've got the hang of this.

Here's the trick that engineers use: make the valid output ranges smaller than the input!

This way the quality of the output signal is always better than the quality of the input signal and even if there is noise on the input, the digital device will get rid of it but producing a better output signal.

This trick even has a name: Engineers call the difference between the valid input and output ranges the noise margin.

>> Dude: Noise margins.

I like it!

Digital devices sound wicked useful.

But can we really build them out of DNA?

>> Sally: Some have already been built I can show you how they work in some cells I've got growing in the lab.

The DNA device you want may be there already and ready to go.

Do you have some time to come to the lab now?

>> Dude: Can I answer in digital?