WHAT DO YOU REALLY KNOW ABOUT CARTRIDGE CHIPS?
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“WHAT EXACTLY IS A CARTRIDGE CHIP?”
“WHAT DOES A CARTRIDGE CHIP ACTUALLY DO?”
“WHAT CAN A CHIP NOT DO?”

The answer to those questions can be both simple and complicated. Because they are now such a large part of our industry, we thought it a good time to cover the origins of cartridge chips and their development through the years. We will also look at the different technologies used, differences in some of the latest chips and possibly most importantly what they can and cannot do.

Through the years cartridge chips have evolved quite a bit, (sometimes faster that the technology used in the cartridges they are attached to). If you haven’t yet, take a close look at the initial picture in this article; there are over 20 years of chips in there.

Before we get started, let’s cover a little chip history...

Before chips, there were a decent amount of cartridges that used electrical fuses of one shape or another.

They were cheap and easily replaced.

When cartridge chips first appeared, they were very simple and easily resettable. In fact they could be reset with a simple box that would re-write the code. First seen in the spring of 1992 the TEC 1305 engine was one of the first to use chips. The chips used in the TEC 1305 and also the Xerox N24 engine which came out soon after were fairly simple devices.
HP at first also used very simple off-the-shelf chips for the Color LaserJet 4500. They just plug into a socket. You can see the progression of HP chips through the years in the aftermarket chips. There is the old 4500 IC, first RF chip, one of the first SMT (surface mount technology) boards and finally the microprocessor versions used today.

Lexmark has been one of the most challenging OEMs for our industry. The Optra T (4069) wasn’t too bad to overcome, but with the release of the T520 series, our world changed.

One of the first aftermarket solutions was to have a wired large board that actually used the used OEM chip in a “piggyback” style. It was wired to a small pass-through board that fit into the OEM slot.

Then came the first stand-alone boards. They started out with somewhat large components that over time were miniaturized as our industry evolved.

Then finally came the new smaller boards with extremely complex encryption codes, which is what we have now.
With few exceptions, all the HP and Lexmark chips have been the contact types, which have plated pads on the boards that touch contacts in the machines when installed (HP 4100, 4600 and 9000 excluded).

Another chip style is the RF (Radio Frequency) type. These chips broadcast a small signal through an antenna to communicate to the printer. The antenna can be a hard wire coil or even a thin label with a flexible circuit printed on it. They can and do look very different from one manufacturer to another.

There have also been some odd shaped chips and cases too. A few of them are shown here. The board that looks like a credit card is inserted into the machine when a new cartridge is installed to reset the counter in the printer.
The latest development for both the OEM and aftermarket is in dedicated microprocessor chips. They are designed specifically for one purpose. The programming is actually built-in and is more hardware than software...

MANUFACTURING DEDICATED MICROPROCESSOR CHIPS
The manufacturing process for microprocessor chips is actually pretty interesting. It all starts with sand or silicon in the form of silicon dioxide. The silicon dioxide is purified and melted, and a crystal is grown to eventually become what we call an ingot. They typically weigh about 100 kg and are shaped like a solid cylinder.

The Ingots are sliced and each slice is polished until they have a flawless mirror smooth surface. At this point the slices are coated with photoresist, exposed, etched, and then doped.

Doping is where other chemicals are added to specific places to change the way the silicon conducts electricity.
Now depending on what is being manufactured, other layers or copper leads are added.

This wafer measures 6" in diameter.

The wafers are tested and then sliced so that the wafer produces thousands of chips.

For the HP P4015 there are approximately 15,000 chips with encryption per wafer. They are now packaged so the chip can be hardwired and for the purposes of our industry, installed on to a small circuit board.

Shown above are some close up views of the chips in the wafer. That’s a very simplified explanation.

For anyone interested, Intel has a great informative page on their website. Here is a link for it:

ARE ALL DEDICATED MICROPROCESSOR CHIPS EQUAL?
So since all microprocessor chips are made basically the same way, are they all equal? Not so much. They may all be manufactured the same way, but the design can be very different.

There are two basic types in the field right now. Some are designed not to have an encryption module. The encryption module is what calculates the response to the question the printer is asking.

Less expensive chips do not have this module. They emulate existing chips in that they can answer all the current questions, but if there were to be a firmware update that posed new questions, or even the same question but asked differently, they cannot respond correctly and the printer will show an error. The reason for the two types is cost. The encryption module takes up a lot of space on the chip die. The larger the die, the less chips per wafer and the higher the cost per chip. Shown are layouts of both style chips.

The layout on the bottom shows the encryption (Module #4). If the chip has this encryption module, then it can emulate the OEM 100%.

Firmware updates will not matter because this module actually calculates the correct answer. It doesn’t just send a programmed answer like the less expensive chips do. While not in use (yet) newer machines and chips from HP have the ability to run a second verifying command.

Only chips with the encryption module will be able to send the correct response. If you’re not sure which style chips your vendor is selling, ask them.
WHAT IS A CARTRIDGE CHIP?
Now that we’ve covered a short history, we still have the questions...

WHAT EXACTLY IS A CARTRIDGE CHIP?
WHAT DOES A CHIP ACTUALLY DO?

Let’s start with what cartridge chips are...
1. **Cartridge chips are devices that communicate with a machine through either direct contact or RF (radio frequency).**
2. They typically are mounted on a small circuit board.
3. They have memory to store information.
4. Sometimes have a processor to provide the correct responses.
5. Have a power control circuit to feed the processor when needed.
6. Provide power protection from voltage spikes, etc.

The chip usually...
7. **Contains cartridge specific information (So the machine knows the correct cartridge has been installed).**
8. Lists the cartridge yield.
9. Lists the region (worldwide, some printer manufacturers use a different chip code for different geographical regions).
10. **Provides authentication to allow communication.**
    • Must answer machine challenges correctly
    • Use the correct encryption
    • Answer within a specific time frame
11. **Holds data as needed to allow the machine to manage the toner use.**
    • The machine determines the toner level and writes this information to the chip
    • The chip will send this information back to the machine as requested
12. **Stores ongoing machine information as the cartridge is used.**
    • The machine counts the pages printed and stores this info on the chip
    • The machine counts the pixels printed (page coverage) and also stores this on the chip
    • The chip will send this information back to the machine as requested

It should be noted here that early versions of machines did not have very accurate page-coverage calculating systems. They have improved immensely, but still are not perfect.

So now we know what a chip is. Now we come to the next question...
WHAT DOES A CARTRIDGE CHIP ACTUALLY DO?

1. The chip will store information on the cartridge part number, yield and region, and will send the information to the machine when requested.

As the cartridge is used, the printer will send the chip information on the pages printed, page coverage and estimated toner remaining. This information is stored on the chip and will be sent back to the printer as requested.

2. The machine is the master. It first sends the data to the chip and then reads the chip data back as needed on all the above items.

3. The chip is the slave. It must be capable of correctly responding to the machine in a certain time frame using the correct encryption:
   - Correct cartridge info (part number)
   - Correct region
   - Cartridge new or used
   - If used, the page-count and page coverage
   - Toner remaining in the cartridge

4. The chip information MUST match the yield for the toner load.

5. Chips are not able to compensate for large changes. Mismatched info will result in errors.

OK, so now we know what a chip can do. Now let’s take a look at...

WHAT A CHIP CANNOT DO

1. A chip does NOT control the yield.
   Chips are preprogrammed with the start yield, but the machine determines the page count, page coverage, toner low and toner out. The machine does write this info to the chip so when requested, the chip will report it back, but the initial determination comes from the printer.

   Once "toner low" or "toner out" is written to the chip, it becomes irreversible. This is why if you have a bad electrical contact to a magnetic roller and get a toner low error; even after you fix the contact issue the cartridge chip will still report a toner low condition. Once these errors have been written to the chip, the only way to clear it is to replace the chip.

2. Chips do not shut a machine down at a certain page count.
   Chips do not have this ability. Machines will use the information stored on the chip to determine if or when it should stop printing, but that information initially came from the machine, and was not calculated by the chip.

3. Chips do not control toner level information.
   This is also something that chips do not have the ability to do. The machine determines the toner level by counting the number of pixels. The machine uses a formula to calculate the amount of toner used per pixel and stores that data on the chip. Some machines also have mechanical, electrical or optical methods of determining the toner level. Again, this info is stored on the chip, but is not determined by the chip.

   For a chip to determine the toner level, pages printed, etc., it would need to be incredibly complex and would take up much more space than would be economically feasible. Why duplicate expensive circuitry over and over when you can do it once in the machine itself?

4. Chips cannot give an error message.
   The machine contains all the circuitry needed to generate error codes. If the machine cannot see or read a chip, it will generate an error code, but it always comes from the machine, not the chip.
WHAT IS THE BEST WAY TO HANDLE CHIPS IN PRODUCTION?
While most microprocessor type chips are more resistant to static electricity damage (ESD) than other types, it can still happen and normal IC type chips can still easily be damaged by it.

Here are a few precautions you can take on the production line to minimize any issues. While ESD can happen anytime, it is more problematic when the humidity is very low (think walking across a rug in your socks in the winter time and touching a metal door knob).

1. Do not remove chips from their packaging until ready to use.

2. Make sure handlers are grounded.

3. Do not dump chips into bins or onto tables/benches.

4. Do not use compressed air or a vacuum to clean the cartridge after testing.
Just wipe them down with a clean cloth if needed (don’t wipe the chip!). The air movement from compressed air or generated by a vacuum can cause a static charge to build up. Even statically grounded vacuum systems can cause issues if the environmental conditions are right.

5. A visible strong shock (like you get when walking across a rug in the winter and touching something metal) is ESD, but not the typical type you would ever see on a production line. Most times ESD is not visible and you would never notice any damage took place. Following the above guidelines can help minimize any damage that might happen.

CONCLUSION
Like it or not, cartridge chips are now an integral part of our industry. We don’t see them going away anytime soon. In fact, following recent trends, they are probably going to get more complicated. Cartridge chips continue to get smaller so it’s our opinion that while they may become more complex in their code, the functions they can perform will stay basically the same.

While for the most part, cartridge chips (as far as our industry is concerned) are considered more of a nuisance, they actually can be very helpful. By storing the data that they do, we have a pretty good record of what the customer is doing built into the cartridge. When a customer calls to say that the cartridge only printed a certain number of pages before it ran out of toner, you have a way of determining the actual page count, and also for many newer machines the percentage of coverage on the page. This can either validate what the customer thinks is happening, or be used to educate them.

Like the printers they work with, chips seem to be following the “smaller, better, faster” axiom. They will continue to evolve, but so will our industry. The one constant I can say will never change is that it will never be boring!