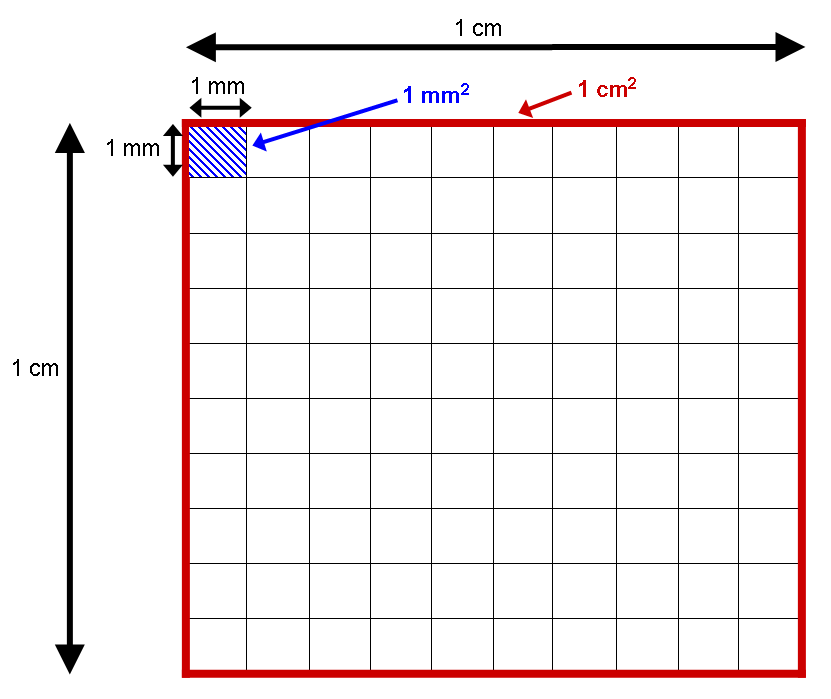
**Get Your Technology Out of My Math!**

Transistors are the most essential component to any electronic device. Without the transistor you would not have a cell phone, IPad, television or computer. Since the creation of a transistor there have been great strides into making them faster, smaller, and use less energy. Look through the timeline given by computerworld.com:

* The first transistor was about the size of the palm of a hand, with a depth of two matchbooks stacked on top of each other.
* The first commercial device to use a transistor was the Sonotone 1010 hearing aid, created in 1953.
* The first transistor radio, the Regency TR-1, went on the market for $49.99 in 1954. The radio contains four transistors.
* Sony Corp. introduced the first portable, transistorized TV, the TV8-301, in 1960. It had a 5-in. screen and used 23 silicon and germanium transistors.
* Intel Corp.'s Gordon Moore in 1965 came up with what came to be known as Moore's Law, which stated that the number of transistors on a chip will double about every two years. Forty-two years later, Moore's Law still holds true.
* Busicom introduced the first single-chip, pocket-size calculator, the LE-120A HANDY, in 1971.
* In 1983, Motorola Inc. introduced the first commercial mobile phone, the DynaTAC 800X. It was powered by transistors and cost $3,995.
* A 45-nanometer Penryn chip (108 mm2) from Intel holds 820 million transistors.
* Intel estimates that about 10 quintillion (or a 1 followed by 19 zeros) transistors ship each year. That 10,000 times the number of ants on Earth.

(1) If a chip is 108 mm2 what are some possible dimensions of the chip itself?

(2) The picture below represents a square cm with the shaded box being a square millimeter, using some of the dimensions you found in (1) use the given notecards to create a “chip” equal to the area of 108mm2. Can you create a chip that is not rectangular? Use the note card to create this new “chip”. Cut out these chips. Now place the chip on one cell phone or tablet. Measure the area of your device. What percent of the area of the device is the central processing unit?

(3) Sometimes different parts of the chips must communicate with each other. So do you think it would make more sense for the chip to be closer to square or a long rectangle?

Transistors themselves can come in many types that work in many different ways. We will not spend time on how they work but will look at different dimensions that are associated with design and performance. First we will look at the areas of different types of transistors and then compare those units with which we are more familiar. First we need to understand that measurements of transistors are done with the units of nanometers. There are 1000 micrometers (µm) in a millimeter and 1000 nanometers in each micrometer (also recall there are 10 millimeters per centimeter). A nanometer is a measurement that is visible only in the atomic level (yes, we are talking about looking at atoms). If it helps you to think about your skin, you know it is made up of cells but you cannot see an individual skin cell. So microprocessors are made up of transistors but you cannot see each transistor. Now when we are looking to find the area of a transistor it depends on the particular type of transistor we are looking for. We will work through some of these together and then you will be expected to find the area of a new transistor type from a given generation. First we will look at a simple transistor device with area formula of:

|  |  |
| --- | --- |
| Generation | F Value (nm) |
| Current Generation | 7 |
| Previous 1 | 14 |
| Previous 2 | 22 |
| Previous 3 | 32 |
| Previous 4 | 45 |
| Previous 5 | 65 |
| Previous 6 | 90 |

|  |  |
| --- | --- |
| Parameter | Typical Value |
| Transistor width (*w*x / F) | 4 |
| Spin contact width (*w*s / F) | 1 |
| Gate area overhead (Mgate) | 1.5 |
| Pitch metal (pm) | 4F |

aint = (*w*x + 2F)(pm + 2F).

Where some values are found in your parameters table and some values are determined by the given generation.

(4) In the parameters table what is the relationship of the transistor width? What is the relationship of the spin contact width?

(5) What do I get when I isolate *w*x? Isolate *w*s?

(6) Draw and label a diagram for the simple transistor device.

(7) Simplify the given area formula so we can find the area of a transistor at the current generation. What would we have to change if we were looking at a different generation?

(8) What are the units of measurement for the area of this transistor?

(9) What is the area of this device in terms of square millimeters? In terms of square centimeters?

(10) How many transistors would fit into a square millimeter? In a square centimeter?

Now let us look at a different transistor type. There is a transistor that is called a fanout-4 inverter. The given area formula is:

ainv4 = 2pm · (3pm + 2*w*x)*M*gate.

(11) Are there any new pieces of information needed for the area of this transistor, if so what are it?  
  
  
  
(12) Simplify the given area formula so we can find the area of a transistor at the current generation.

(13) What is the area of this device in terms of square millimeters? In terms of square centimeters?

(14) How many transistors would fit into a square millimeter? In a square centimeter?

Now let us look at our last transistor type. There is a transistor that is called a NAND2 gate. The given area formula is:

aNAND = 3pm · (3pm + 3*w*x)*M*gate.

Attempt to answer the following questions on your own. If you get stuck refer to the previous 2 examples before raising your hand and asking for help.

(15) Are there any new pieces of information needed for the area of this transistor, if so what are they?

(16) What is your given generation?

(17) Simplify the given area formula (in terms of F and Mgate) so we can find the area of a transistor at your given generation. Why would it be best to simplify the area formula before plugging in the values?

(18) What is the area of this device in terms of square millimeters? In terms of square centimeters?

(19) How many transistors would fit into a square millimeter? In a square centimeter?

We will finish today’s activity by looking at the energy needed to run a transistor. The energy for a transistor is given by the formula:

|  |  |  |  |
| --- | --- | --- | --- |
| Generation | F (nm) | Cdev | Vdd |
| Previous 2 | 22 | 3.45E-16 | 0.5 |
| Previous 3 | 32 | 4.60E-16 | 0.6 |
| Previous 4 | 45 | 5.84E-16 | 0.7 |
| Previous 5 | 65 | 5.82E-16 | 0.8 |
| Previous 6 | 90 | 7.96E-16 | 0.9 |

Eint = CdevV2dd.

E stand for the energy for each transistor on the device. C is the capacitence of the device, which means how well the device can store an electrice charge. Lastly V stands for the voltage needed to run a transistor.

(20) What are the energies for the given generations from the table above?