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Hardware and Software Resolution For a Pointing Device

INTRODUCTION

The rated differences in pointing device resolution can be confusing to the user; this application note describes the method for calculating hardware resolution of a pointing device that incorporates Microchip's MTA41XXX Mouse Controller. It also includes an explanation of the software controlled resolution for these same devices. Mice and trackball resolution is rated in terms of DPI (Dots Per Inch). This resolution may be controlled via hardware or software, but specific differences exist in each case.

THEORY OF OPERATION

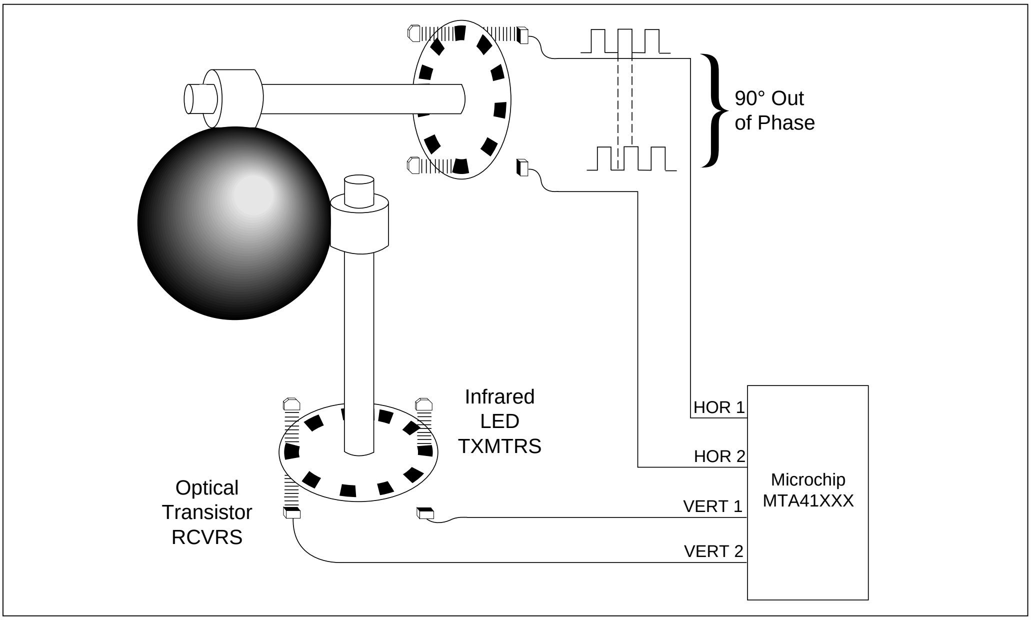
The basic hardware resolution or DPI of a mouse can be found using the following formula:

$$DPI = \textit{Rev per inch}_{roller} * \text{Logic states per rev}$$

Refer to Figure 1 for a visual representation of the following material. A standard motion translator for mice is the use of two slotted wheels, one each for horizontal and vertical direction. Also, there are two optical receivers per slotted wheel. As the slotted wheel turns, infrared beams of light are alternately transmitted and blocked, thereby sending a series of ones and zeros to the optical transistor receivers. The two optical receivers are offset from each other such that the resulting signals are 90° out of phase. This phase difference results in two distinctly separate signals. The controller interprets what direction the mouse is moving along either axis by the order in which it receives these two signals. It should be noted here that the number of closed slots or bars on the wheel is equal to the number of open slots. From this information, the number of logic states per revolution is calculated as follows:

$$\text{Logic states per rev} = \textit{Optical RCVRS}_{wheel} * (\textit{Windows}_{wheel} + \textit{Bars}_{wheel})$$

FIGURE 1 - TYPICAL ELECTRO-MECHANICAL MOUSE OPERATION



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Hardware and Software Resolution for a Pointing Device

Before we can calculate the number of roller revolutions per inch of mouse travel, the number of ball revolutions per inch of mouse travel must first be calculated. This is accomplished below by dividing the ball circumference, or pi times the ball diameter, into the unit of interest.

$$\textit{Revolution per inch}_{ball} = 1\text{inch}/\textit{Circumference}_{ball}$$

At this point, we can see that the number of roller revolutions per inch of mouse travel can be found by multiplying the number of ball revolutions per inch times the ratio derived from dividing ball circumference by roller circumference.

$$\textit{Revolution per inch}_{roller} = \textit{Revolution per inch}_{ball} * (\textit{Circumference}_{ball}/\textit{Circumference}_{roller})$$

Refer to Appendix A for an example of the above calculations using typical mouse specifications. Table 1 includes actual specifications and resulting DPI calculations using the information in this note.

SOFTWARE MODIFICATION OF DEVICE RESOLUTION

Now that the foundation for the basic physical (true) resolution of the mouse or trackball has been established, let's explore how this can be modified with software running on the host computer (device driver), or by the mouse controller. It should be noted here that most graphical user software is designed to operate most efficiently within the 200-400 DPI range.

Since the basic resolution of the device is set by the tracking system, it cannot be increased by software. However, software can provide true lower resolutions by applying fractional gain factors (e.g. 1/4, 1/2) to the actual count reported by the encoders. Software can also provide variable or fixed scaling factors that multiply the actual count (e.g. 2, 4, 8). Refer to Table 2 for some examples of software fractional gain and scaling effects on the hardware resolution of different pointing devices. <u>These scaling factors are sometimes mistakenly interpreted as having the ability to increase the true (hardware) resolution</u>. In general, software scaling factors that increased the number of counts reported per inch of mouse movement contribute to a loss of granularity, especially if a fixed scalar is applied. Variable scalars (often referred to as ballistic gain) that apply a multiplier based on the number of incoming counts can supply increased or decreased counts per inch without a degradation in granularity at low mouse velocities. The primary purpose of these scaling and resolution modes is to alter the mouse's motion sensitivity to suit the individual user.

If given a command from the host or some other means (e.g. hardware switch on the mouse), the mouse controller can also perform these tasks. The MTA41110 supports the command method, which is the most efficient in terms of hardware cost. When the MTA41300 is configured for the RS232 interface option, it is a transmit-only device, thereby not supporting the host-command mode. In the PS/2® interface mode the MTA41300 controller will respond to the PS/2 "*Set Resolution*" command. However, this response is only for software compatibility purposes, and the true resolution remains fixed.

The MTA41110 implements the complete IBM PS/2 specification, including the software fractional gain and variable scaling modes. The host driver software must be capable of issuing commands (e.g. "*Set Resolution*", "*Set Scaling*", etc.) to the MTA41110 controller in order for the user to benefit from these built-in firmware functions. The MTA41300 is a fixed-resolution device and any desired software resolution and scaling modes must be performed by the driver software.

Software gain and scaling modes can also be implemented by the device driver software that runs on the host computer. This method is very efficient since it only requires a small amount of additional code, which executes on the host system. Users also gain access to a wider variety of fractional gain and scaling factors than can be cost-effectively implemented in the mouse controller. The mouse control panel under Microsoft® Windows™ is a good example of such host software-controlled gain and scaling factors.

TABLE 1

	IBM PS/2 Mouse	Microsoft Mouse	Apple® Mouse	Trackball
Ball Diameter	0.86 in	0.87 in	0.86 in	2.25 in
Ball Circumference	2.702 in	2.73 in	2.702 in	7.07 in
Roller Diameter	0.25 in	0.196 in	0.155 in	0.30 in
Roller Circumference	0.785 in	0.62 in	0.487 in	0.94 in
Ball Revolutions Per Inch	0.37	0.37	0.37	0.14
Roller Revolutions Per Inch	1.273	1.63	2.054	1.05
Windows Per Wheel	40	64	24	24
Bars Per Wheel	40	64	24	24
Logic States Per Revolution	160	256	96	96
Dots Per Inch	203.718	417.07	197.147	101.09

As a general note, the PS/2 specification may be somewhat confusing regarding device resolution. It specifies software-implemented resolution modes for a PS/2 system, including the encoder hardware. Also, it defines software commands, sent to the controller from the host, in terms of this absolute resolution. For example, the options for the "*Set Resolution*" commands are 1, 2, 4 and 8 counts per millimeter (25, 50, 100 and 200 DPI). These options actually instruct the mouse controller to divide the incoming count by 8, 4, 2, or 1 respectively, then report the divided count to the host. The actual hardware resolution of the IBM PS/2 mouse is 200 DPI. Therefore, for mice whose hardware resolutions are not 200 DPI, the "*Set Resolution*" command will not be the actual available resolution, rather the available resolutions will be ratioed relative to a 200 DPI (hardware) mouse.

DYNAMIC RESPONSE

There is a maximum linear velocity at which the mouse can be moved and be 100 percent effective. Operating the mouse faster than this will result in missed quadrature information. This section will show the derivation of that maximum velocity.

According to the MTA41110 data sheet, the HOR and VERT outputs are sampled at ~8700 samples per second.

Sample Rate = Frequency
Period = 1/Frequency = 1/8700 Hz = 114.94μsec

The hardware interface of the Microsoft mouse which was referred to earlier will be used as the example for this discussion. It has 64 slots per wheel, which results in 256 logic states per wheel revolution. The equation below displays the method for calculating the wheel's maximum rotation rate.

$$Period_{wheel} = (256*114.94\ \mu sec) = 29.42\ msec$$

$$Frequency_{wheel} = 1/Period_{wheel} = 33.98\ rev/sec$$

Since the roller and wheel are attached on the same shaft in a one-to-one relationship, the frequency of the roller must also equal 33.98 revolutions per second.

The velocity of the roller can then be found with the following equation. Remember, the roller radius is .098 inches. Refer to the Microsoft mouse section in Table 1 for this information.

$$Velocity_{roller} = 2*Radius_{roller}*Frequency_{roller} = 20.9\ in/sec$$

Because there is a direct correlation between mouse travel and travel along the surface of the tracking ball, the velocity of the mouse can also not exceed 20.9 inches per second.

CONCLUSION

From the calculations in the body of this note, it is shown that the mouse controller has no effect on the resolution of the mouse or trackball. DPI is completely a function of mechanical design.

APPENDIX A

These detailed calculations show how the resolution of a typical mouse is determined. They show how the physical design of the motion tracking system (encoder wheels and tracking rollers) determine the basic (hardware) resolution of the mouse. This analysis assumes that the mouse controller can report one count to the system for each logic transition at the motion encoders. This applies directly to the MTA41300 and MTA41110 Mouse and Trackball controllers since they both contain modes that report one count for each motion encoder state. The MTA41110 also contains software resolution modes which will be discussed later in this analysis.

First, let's begin by sizing a typical tracking ball and roller. The roller is a small diameter wheel placed in contact with the main ball.

$$Diameter_{ball} = 0.86\ in$$

$$Circumference_{ball} = \pi*Diameter_{ball} = 2.702\ in$$

$$Diameter_{roller} = 0.159\ in$$

$$Circumference_{roller} = \pi*Diameter_{roller} = 0.5\ in$$

Now let's see how many revolutions the tracking roller makes in one inch of mouse movement.

$$Revolution\ per\ inch_{ball} = 1inch/Circumference_{ball} = 0.37$$

$$Revolution\ per\ inch_{roller} = Revolution\ per\ inch_{ball} * (Circumference_{ball}/Circumference_{roller}) = 2.002$$

TABLE 2

	True DPI	x2	x4	x0.5	x0.25
IBM PS/2 Mouse	200	400	800	100	50
Microsoft Mouse	400	800	1600	200	100
Apple Mouse	200	400	800	100	50
Trackball	100	200	400	50	25

NOTES: The examples given in this application note are:
1. Hardware examples for illustration purposes only.
2. Do not imply the use of MTA41XXX devices by the respective manufacturers.

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Notice that the size of the tracking ball has no effect on the number of revolutions the tracking roller makes in one inch. This is because one inch of mouse movement corresponds directly to one inch of movement along the circumference of the ball. However, roller size does affect basic resolution.

Let's examine the physical design of some normal and high resolution encoders, and see why they are a key component in determining basic resolution. The roller and an encoder wheel are usually mounted axially on a single shaft, resulting in a one-to-one relationship between the roller and encoder wheel.

Optical receivers per wheel = 2

To determine the direction of movement, quadrature output is needed from the encoders. Standard industry practice is to use two optical detectors (e.g. phototransistors) for this purpose.

Windows per wheel = 25
Bars per wheel = 25

The number of windows and bars in the encoder wheels determines the number of pulses per revolution from the encoder.

Now let's calculate the basic physical revolution in DPI (Dots Per Inch)

$$\text{Logic states per rev} = \textit{Optical Rcvrs}_{wheel} * (\textit{Windows}_{wheel} + \textit{Bars}_{wheel}) = 100$$

The basic resolution in DPI can now be calculated as:

$$\text{DPI} = \textit{Rev per inch}_{roller} * \text{Logic states per rev} = 200.195$$

Now let's analyze a typical high resolution mouse. Typically, "high" resolution mice and trackballs contain more windows in the encoder wheels. This results in higher resolution since more pulses are created for each revolution of the wheel.

Windows per wheel = 50
Bars per wheel = 50

$$\text{Logic states per rev} = \textit{Optical Rcvrs}_{wheel} * (\textit{Windows}_{wheel} + \textit{Bars}_{wheel}) = 200$$

$$\text{DPI} = \textit{Rev per inch}_{roller} * \text{Logic states per rev} = 400.39$$

<u>Doubling the number of windows in the encoder wheel(s) converts a true 200DPI mouse into a true 400 DPI mouse.</u>

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