Magic Image Wand

Using TTGO T1 (T-Display)

# Introduction

## History

This design was inspired but not copied from the PixelStick commercial product. I have not owned, used or even touched an official PixelStick, I haven’t even read their manual. I did briefly look at the marketing material on their website to get an idea of how it worked. I was also inspired by the light wand developed by photographer Michael Ross. I started out building one following Michael’s instructions. It used the Mega2560 Arduino and a 2-line display with some buttons. I started adding features and quickly ran out of memory. I also wanted to support a second 1-meter LED strip. At this point I decided to do a total rewrite and use the newer much faster esp32 modules. This let the feature list grow and the additionally the strip display speed was increased dramatically. The first version used an OLED display esp32 from Heltec. After that I discovered the TTGO with a color TFT display. After some more code re-writing and feature adding the TTGO version was created!

## Version 1.82

This is the software version used for this documentation.

## Using with Your Camera

Put your camera on a tripod and set it for a long enough time exposure so the shutter is open for at least the time it takes to display the image. Stand at your chosen starting position and open the camera shutter. Press the Image Painter start button and walk from right to left (looking at the camera), or left to right if you prefer, it is adjustable from the menus. Walk smoothly or erratically and hold the wand in the same position or wave it around. Use your creativity and see what kinds of images you can create.

## Description

The Magic Image Wand consists of the following major parts. The parts are all connected together into a single unit. The optional second LED strip is easily removed or added so the system fits into a smaller space.

1. LED strip. This is an aluminum extrusion with 144 LEDs and a diffuser cover. The LEDs are available with an adhesive backing that is used to stick the strip inside the extrusion.
2. Fixed Handle. The rotary control button is on the handle which is used to hold the Image Painter. The button is under your thumb and can be pushed and rotated.
3. Rotating Handle. This is useful when two LED strips are attached. It allows the user to spin the light stick.
4. Control Unit. This box holds the ESP32 computer that runs the LED strips and reads the rotary button switch.
   1. TFT Display. The TTGO T1 ESP32 module used includes a small TFT display that is used to show the file selections. It is also used to show menus so that the various settings can be changed. It can even display a preview of the image file.
5. 18650 Batteries. These are the rechargeable batteries that run the control unit and the LED strips. They are held in the case underneath the handle.
6. ARCA tripod mount. This can be placed anywhere on the lower LED strip. It is used for holding the MIW on a tripod which is very useful when using it as a light source. The mount is also used to adjust the balance when using the spinner handle. It can be moved up or down until the balance point is at the spinner handle. This will make rotation much smoother.
7. There are two LED end caps that protect the end of the aluminum extrusions holding the LED strips.
8. Roller Encoder Wheel. This wheel is used to control the display speed while rolling on the ground. It will allow for very exact image timing. The good news is the software supports it but the bad news is that the hardware mount for the wheel has not been designed yet.

## 144 or 288 pixels

The Magic Image Wand uses one or two WS3812B pixel strips that have 144 pixels per meter. Each meter strip is made from two 72-pixel strips. This results in a slight gap in the middle that can be seen in some images. When the second strip is installed the power and data wires make it difficult to get the pixels close together. This results in a dark gap in the middle of the two strips that can be seen with some images. This problem can be avoided by running wires to the ends of the strips instead of the middle. There is an option in the settings to handle this.

The LED count can be set if strips other than 144 are desired.

## Limitations

At full brightness, each strip uses 43 Watts when all the LEDs are lit. If full brightness is required then the voltage regulator must be able to supply enough current. However, some images do not have all of the LEDs lit at the same time so the brightness can sometimes be set to full power. For example, if the strip never has more than half of the LEDs on then the power consumption is only 21 Watts. In practice however I have found that due to the long night exposures it is seldom necessary to go brighter than about ¼ power.

There is a setting in the menus that will automatically limit the amount of power used by the strip. This can save the voltage regulator from overheating.

## Processing BMP Images

The images can be either 144 or 288 pixels in height. They must be rotated 90 degrees CCW and saved as 24bit color in Windows byte order. They can have as many pixels as desired for the width. The easiest way to build an image is to create the image as 144/288 pixels tall and as wide as needed. Remember that black will be transparent in the final image. Once the image looks good it can be rotated 90 degrees CCW and saved as a 24-bit bmp file. The bmp file is then saved to the micro-SD card.

There is a website that will convert images into the correct format.

<https://www.essl.de/static/lighty/>

# Examples

I have posted some example photos on youtube.com and thingiverse.com. People more creative than me will create much more interesting images. I am including these just to illustrate a few simple examples. You can also go search the web for PixelStick images to get more inspiration.

Here are the links. The youtube links are for earlier versions.

<https://www.youtube.com/watch?v=2L3TWKf_4T8>

<https://www.youtube.com/watch?v=_nibSs949mA>

<https://www.thingiverse.com/thing:4660045>

<https://www.thingiverse.com/thing:4613446>

<https://www.thingiverse.com/thing:4815316> the TTGO version

# Button Operations

All operations can be controlled by the rotary push button on the handle, this makes the image painter usable with one hand. Read about btn0 and btn1 below. The display shows the options and settings and filenames. The dial can be rotated left or right to choose items. The button is clicked to select the current item. A long press is used to access other options and is done by holding the button down for about a ½ second or longer. This long press time is also adjustable if a longer or shorter time is preferred. The system has two modes of operation. After booting the display shows the currently selected file. Rotating the dial left and right will move through the files on the SD card, or the internal patterns if they have been selected. Clicking the button starts the LED strip display. At this point the user walks around with the wand or waves it around depending on what effect is desired. The display shows the progress of the file and how much time is remaining. Settings are available to control the display speed, repeating the file, or even automatically skipping to the next file. The image can even be played twice, first forward and then backward for a mirror like effect. There is a chain option that will play all of the files from the current selection to the final file in the current folder. The brightness of the LEDs are of course also adjustable to balance the lighting with the rest of the scene.

To adjust settings a long press is used on the dial or a simple press on btn1 which will open the last menu that was used. A long press while in the menus returns to the normal play mode. Each menu except the main menu has also at least one entry to return to the previous menu. Note that btn0 can also do this.

## Dedicated Buttons – Button0(bn0) and Button1(btn1)

There are two dedicated buttons on the top left of the TTGO device. The top one is called btn0 and the bottom one is called btn1. Both these buttons support both clicking and long presses. A long press of both buttons will reboot the system The functions of these buttons depend on the current operating mode as described next. Common to all modes is that clicking btn1 will always emulate a long press of the dial button.

### btn0/btn1 During Run Mode

btn0 will preview the current BMP file. This easier than navigating to the menu entry that does the image preview.

Long btn0 rotates the display through all four possible positions. If the display is upside down, the image file will also be rotated upside down. This is useful when using a single strip and holding it high in the air. A long press on the lower button turns on the lightbar feature. These actions can be modified in the system menu.

### bnt0/btn1 During Menu Mode

btn0 returns to the previous menu. It does nothing if at the top menu. Long btn0 returns to the top menu no matter what menu level is currently displayed.

Long btn1 acts same as clicking the dial button.

### btn0/btn1 During Integer Entry

btn0 cycles through the allowed increment values. Long btn0 resets the value to the original value. btn1 or dial click saves the new value and closes the number entry.

### btn0/btn1 During Light Bar

btn0 cycles through the available increment values. Long btn0 increments the delay value which affects the auto cycle mode of the light bar. btn1 or dial click closes the light bar.

## File Control Settings

There are more details below in the section on menus but here is a quick list of the things that can be changed for controlling the image display.

1. LED brightness.
2. Color Balance. Set the white balance for special effects or to correct color casts.
3. Gamma Correction. Adjust the display to match closer to our color vision at different brightness levels.
4. Column time, how long each frame is displayed. Note that even when set to 0 there is a minimum time which is determined by the amount of time used to load the LED’s. See the menu section below for more details. Frame advance can also be set to manual so the frame only changes when the button is pressed, or the dial is rotated.
5. Fixed display time. It is also possible to have the system calculate the frame hold time. You just set how long in seconds you want the image to take and it will set the correct frame time based on the image size.
6. Reverse. This allows the user to walk from right to left or left to right.
7. Upside Down. This allows the user to hold the wand high in the air without modifying the image file.
8. Pixel Double. This uses two pixels for each one so a 144 pixel images can be displayed on the entire 288 pixels when two strips are installed.
9. Scaling. This will reduce a 288-pixel image to 144 pixels.
10. Mirror. Plays the file twice, first forward, and then in reverse.
11. Chain. Plays all the files from the current file to the last file in the current folder. Files are always in alphabetical order.
12. Start Delay. A wait after pressing the button until the file starts. All delays are specified in 1/10 seconds.
13. Repeat Count. How many times to repeat a file.
14. Repeat Delay. A wait in between file repeats.
15. Chain Repeat. How many times to repeat a chain.
16. Chain Delay. A pause in between chain repeats.
17. Built-In or File. Choose files from the SD or from a set of built-in patterns.
18. Change settings for various built-in patterns.
19. Select Folder. Choose a folder on the SD card to look for BMP files.
20. Display Settings. Control some menu operations and display options.
21. MIW. Manages files that change settings for folders and files. These setting files are loaded when a folder is selected or when a file is run. The settings for a file revert to the original values after running the file. These files are also text and can be edited if desired for special operations. The file version will apply the settings when the named file is displayed. The folder version is loaded when a folder is selected.
22. Saved Settings. Change the settings that can be optionally loaded at boot time. It is also possible to save the current settings and manually load them when needed.
23. Macros. There are ten macro slots (0 to 9) available. Each of these can either load all of the settings or run a recorded sequence of operations. The record command records the images as they are played and the same sequence can then be played again using the run command. The save command stores the current settings which can then be restored with the load command.
24. A dedicated button on the TTGO is used to preview the BMP file on the display.
25. The other dedicated button performs the same operation as a long press on the dial button.
26. Reboot. This will reset the system. It can of course also be done by unplugging the battery from the power supply or including a power switch for the power.

## Rotating and Clicking Button

The handle button is rotated and clicked to select different files, menu items, and to change settings. In the menus, boolean values toggle with each click. Multiple selections cycle through all the available options. Integer values go to another screen that shows the minimum and maximum values. Rotating the dial right increases the value while rotating to the left decreases it by the increment amount. The increment amount can be changed by clicking the button which will cycle between different values. One of the values will be a reset to the original value, activated with a long press. A long press is also used to accept the new value and return to the menu. A \* indicates the active menu line. A + in front of the menu means another menu will be activated. The “Return…” menu goes back to the previous menu when clicked. A long press will return to file select/run mode. The current menu entry is remembered so that it will return to the same place when the long press is done from the select/run screen.

In select/run mode the current file is displayed on the top line. Optionally the next three files will be displayed below. Rotating the dial right moves the next file to the top line and rotating left moves the previous file back. By default it will stop at the first and the last file. An option allows rollover, so going left from the first file moves to the last file and moving right at the last file will display the first file again. This option also causes menus to behave similarly.

When a file is running after clicking the button the top of the display will show the progress of the file. The current filename is displayed. The line under the file will show the remaining seconds for the file. The rest of the screen will show the various delays, repeats, and chain information when those options are activated.

### Button Menu Operations

Left/ Right

Select menu

Select file

Inc/ Dec integers

Long press

Open menu system, goes to the remembered menu point

Return to run mode, the current menu point is remembered

Accept integer

Click

Run file when in run mode

Select menu item, including return to previous menu

Toggle booleans

Rotate through multiple selections

# Menus

There are two menu set, full and simple. The full one contains all of the options and can be somewhat time consuming to navigate during normal use. The simple menu has the most used options and is very short.

All menus except the main one have the first line indicating what menu this is. There is a ‘-‘ in front that indicates clicking on this menu will go back to the previous menu. Submenus also have the last entry as “-Back” which will return to the previous menu.

# Simple Menu Details

## Menu: Simple

This is a toggle between the full and simple menus. It names the current one in case it isn’t obvious! Just click on it to change to the other one. The setting will be remembered across rebooting.

## Images: SD Card BMP | Built-In

This will show which images are currently available, the built-in ones or the SD card BMP files.

## Column Time: 10 mS

This displays the current frame time and can be used to adjust the time. It can adjusted from 0 to 500 mS.

## Brightness: 30/255

This sets and adjusts the LED strip brightness. 255 is full brightness.

## Run Macro: #(0-9)

This will start running the selected macro number, from #0 to #9.

## Select Macro: #(0-9)

This command will list all 10 macro names with an indicator if it is available or not. Clicking on one will make that the current macro for the run command.

## Sleep

This menu entry makes the MIW enter sleep mode, which uses little power. Pressing any key will wake the system up with the same settings it had before.

# Full Menu Details

Following is a detailed list of all the menu entries and what they do. Menu items that open another menu (a submenu) start with a ‘+’. Most submenus also have a first and last menu entry that returns to the menu above. Depending on the “menu choice” setting found in the menu settings of the system menu, either an ‘\*’ is shown in front of the active menu line or the menu line is highlighted. The top menu will have a small white triangle indicating that there are menu items that are not visible due to scrolling. Just keep rotating the knob to the left and they will appear. Similarly the last entry on the screen will have a small white triangle if there are more menu items below. Scroll right to make them visible as the ‘\*’ or highlight indicator moves down.

The submenu details are also described below after each menu item. Submenus have a ‘+’ at the start.

Some menu items may change depending on other selections. For example, chain options are not displayed unless chaining is enabled.

## Menu: Full

Select this to toggle between the simple and full menu systems.

## Images: SD Card BMP | Built-In

Clicking this selection will toggle between running files from the SD card or using the built-in patterns.

## Preview BMP

This will display the currently selected BMP file on the screen. Note that the upper dedicated button (button 0) does the same operation. This menu item appears only when CD Card is selected. Since the images are 144 pixels and the display is only 135, 9 pixels total are trimmed from top and bottom of the image. The image can be scrolled left and right using the dial if the image is longer than 240 columns. The sideways scroll amount defaults to 120 pixels, but the amount can be set in the system menu display settings menu A single click toggles between the image preview and a screen showing the width and height of the image. Pressing the upper preview button, or a long press on the dial, or the lower dedicated button exits the preview display.

Pressing the button while previewing a file will display a screen with the size of the image in pixels, the length that should be walked for the correct aspect ratio, and how long the image will be displayed at the current column hold time.

There is a dedicated button on the top left that can also be used to preview the file. Pressing it again will return to the previous menu or file selection.

If the images are designed for the second LED strip then the images can be 288 pixels high. The preview function will then ignore every other pixel so the preview will fit in the display.

## +Image Settings

This submenu has the settings that control display attributes of the image files. The frame hold time is also used by some of the built-in image functions.

### Timing Type: Column | Image

This is a Boolean that switches between using a set frame hold time for each column of the image file or a calculated time based on the desired total display time. It is sometimes more convenient to set the total time that the image file is displayed. This mode will automatically calculate the frame hold time such that the image will display for the chosen time. It is possible to request a time that is too fast for the image painter. If the calculated frame hold is less than about 4 mS the software cannot read the SD card fast enough to keep up. The image painter will do the best it can, and the actual time will be displayed on the screen as the image plays.

### Column Time: 10mS

This selection shows and allows to be changed, the time in mSecs (see note below) that each line of information from the BMP file is displayed on the LED strip. It is commonly used to adjust the walking time while the file is being displayed. It is only applicable when Frame Advance is set to auto. The valid range is 0 to 500 mS.

**Note:** This time is actually added to the minimum time that it takes to update the LED’s in the strip. Each bit of information takes 1.2 uS and each LED needs 24 bits. If there are 144 LED’s then the total time to load the data is 1.2 uS x 24 x 144 = 4.32 mS. There is also a reset time at the end that loads the data into the LED’s of >50 uS. Some brands require up to 1 mS so it is safest to assume that the column update time is about 5 mS. This time is added to the time set in the frame hold value, I.E. a hold value of 0 will still have a 5 mS frame time. There might also be additional time required for reading slower SD cards. Also be aware that displaying the file in reverse will slow down due to reading the SD file in the reverse order. A 900 column image would in theory take about 3.9 S. In testing we have found that reading the SD card actually slows this down to about 6 Seconds. Work is being done to try and improve this.

### Image Time: 5 S

When image time is selected as described above in **Column Time** this menu item allows the time to be set in seconds that the image will be displayed. The necessary column time will be calculated and used while displaying the image file. This value will not be saved in the column time so if column time is selected again it will show the original value.

### Start Delay: 0.0 S

This value delays the image display after the start button is pressed. It can be set in 1/10 second increments.

### Fade I/O Columns: 0

This value is the number of columns (aka frames) that will be used for fading in and out during the display of an image file. It does not apply to the built-in patterns. For example, setting it to 20 will mean that the first 20 frames will start at a brightness of 0 and increase to the specified LED brightness. The last 20 frames will fade down to 0 on the last frame. This gives a softness to the starting and ending sides of the image. An option to have separate values for starting and ending has been considered but has not been implemented yet.

### Upside Down: Yes | No

When set, the image pixels will be reversed. This allows the LED bar to be held upside down without making the image upside down. Note that a long press on button 0 will also toggle this.

### Running Dial: None | Brightness | Speed

This menu controls what the dial does during image display. The brightness or speed (column display time) can be changed during display by rotating the dial. This can be used to create more interesting image effects by rotating the dial while walking.

### Walk: Right-Left | Left-Right

This option changes the direction that the file is read for display. This allows the image to play forward or reverse. This allows the user to walk in the other direction or to simply reverse the image from left to right. The default is right to left, looking back at the camera. Right to left is usually best when recording a sequence of images into a macro. The images will then play back in the same order. If left to right is chosen, then the images recorded will play back in the reverse order. This is particularly important when spelling words with the individual letter image files during macro recording.

### Play Mirror Image: No | Yes

This plays the image twice, once forward and then in reverse. This creates a mirror like effect.

### Mirror Delay: 0.0 S

This is the delay before starting the mirror image display after the normal display is finished. I is used to create black space between the two parts of the image.

### Scale Height to Fit: No | Yes

If the image is taller than 144/288 this option will ignore some pixels so that only 144/288 are displayed. It does not do any fancy scaling like Photoshop by looking at adjacent pixels, it simply ignores half of them so the image will fit.

### 144 to 288 Pixels: No | Yes (only when 288 pixels is set)

This doubles every pixel so a 144-pixel image will fill all 288 pixels. Of course, there isn’t any increase in resolution, but it does fill two strips if you don’t have a 288-pixel image.

### Frame Advance: Auto | Step

In auto mode the frame hold time is used. In step mode each line is displayed until the button is pressed, the dial is rotated, or the wheel pulse counter closes the contact. If the frame pulse counter is zero then the dial is used to advance frames. Rotating to the right or clicking will display the next frame from the file. Rotating to the left will display the previous frame. This enables some creative uses of image by rotating the wheel left and right. Note that the mechanical wheel pulse counter has not been designed yet.

### Frame Counter: 0

This value is the number of wheel pulses that will advance to the next frame when manual frame advance is set. Note that this option is set to a non-zero number it disables using the rotary dial to advance frames.

## +Repeat/Chain Settings

This submenu contains settings that are used to repeat and chain images. Except for the chaining option it also applies to built-in images.

### Repeat Count: 1

This is the number of times to repeat an image.

### Repeat Delay: 0.0

When repeat count is greater than one this value will cause a delay before the image starts again. It is set in 1/10’s seconds.

### Chain Files: Off | On

When this option is on all the files from the current one to the end of the last file in the current folder will be displayed. Since filenames are always sorted alphabetically this option will show a sorted list of files. If some other order is desired it is also possible to use the macro command to record the file order for display.

### Chain Repeats: 1 (only when chain files on)

The entire chain will be repeated this many times.

### Chain Delay: 0.0 (only when chain files on)

This time value is applied before starting each chain repeat after the first one.

### Chain Wait Key: No | Yes (only when chain files on)

This is a Boolean setting that when true will wait for a key click or rotation after each file is displayed. You can then decide when to start showing the next file in the chain.

## +LED Strip Settings

This submenu has settings for the LED strip.

### Max Brightness: 25/255

This is the brightness from 1 to 255. Values above about 45 should not be used with the light bar unless the power supply can supply sufficient current. 255 white will use almost 7 amps! The version of the PCB with the onboard power supply can only supply 1.5A continuous. More than that will cause overheating and eventual destruction. High brightness values can be used for shorter image displays of course if there is some cool down time. A minute is usually sufficient for this. In practice it has been found that a brightness level of 15 to 25 is more than adequate for night photography. 7A would likely only be needed in a light bar used for studio lighting.

### LED Controllers: 1 | 2

This is set to “1” or “2” depending on whether you have the second strip installed. There is not any method to detect a strip connected to the second control lines so it must be manually selected. When this value is changed a reboot is necessary because the fastled LED library does not handle runtime changes very well.

### Total LEDs: 144 | (up to maximum value) 512

This is a number specifying how many total LED’s are available. It can be set from 1 to 512. For example, if there are two 144 LED strips, then this should be set to 288.

### LED Wiring Mode: Middle | Serial | Outside

This option allows the wiring to the LED strips to be arranged in different ways to optimize the wand. Putting both LED inputs in the middle of the wand means shorter wires that do not have to extend to each end of the wand, but there will be a larger gap in the middle between the two strips since it is difficult to get the LED strips close with the power connecters there. Putting the bottom strip input on the bottom and connecting the output of the bottom to the input of the top LED allows for only one control wire but there will still be a black stripe in the middle due to the spacing needed for the wires. This is same problem as the first wiring situation. If the top strip has the data input at the top, then the gap in the middle can be eliminated. Make sure no electrical contact happens in the middle between the two LED strips. This approach does mean that it is necessary to run wires out to both ends of the wand, but in return there is no black stripe in the middle when using the wand.

* Middle - Both strips have data input in the middle.
* Serial - Bottom strip is fed data from the bottom and the middle has a connection through to the upper strip. This uses a single contoller while the others can use one or two controllers.
* Outside - The top strip is reversed and there is no connection between the strips in the middle. Both strips require long wires to the outer data feed locations.

### Gamma Correction: On | Off

This option modifies the displayed colors at different brightness levels to more closely match our eyes color perception.

### White Balance R: 255

This manually sets the strip Red brightness Values range from 0 to 255.

### White Balance G: 255

This manually sets the strip Green brightness.

### White Balance B: 255

This manually sets the strip Blue brightness.

### Show White Balance

Selecting this displays the before and after result of setting the RGB levels. It runs for about 5 seconds.

## +Various Built-In Settings

When built-ins are selected and the selected one has adjustable options the menu will appear here. More documentation may be added here later.

## +MIW File Operations

MIW files are files that can load settings and display images. They are text and can be modified by using any text editor on them. The extension is always MIW (Magic Image Wand). There are menu items to create, run and delete them. Depending on the name some of them are automatically run under certain conditions as documented below.

MIW files only control the settings for files, none of the built-in image settings are saved in these files.

### Save start.miw

This creates a file with the current settings. It is run whenever a folder is opened.

### Load start.miw

This will manually run the file in the current folder.

### Erase start.miw

This does just what it says: removes the start.miw file from the current folder.

### +Associated Files

These are command files just like the start.miw file above, but they have the same name as a BMP file, but with the .miw extension of course. The file is run when a BMP file is started for display. This allows specific settings to always be applied to a specified BMP file.

#### Save <filename>.miw

This saves the current settings for the currently selected BMP file.

#### Load <filename>.miw

This loads the settings for the currently selected BMP file. It can be used to verify that the settings are in fact correct.

#### Erase <filename>.miw

This command deletes the file associated the currently selected BMP file.

## +Macros

Macro files are a powerful feature that can be used to record and run a set of images. There are 10 macro files allowed. They are named from 0.miw to 9.miw on the SD card in the root folder. They can also be edited on a computer by using a text editor if necessary. The easiest way to create one is to use the record menu entry as shown below.

Descriptive names can be assigned as described in the information section below.

### Select Macro: #(0-9)

This selects the current macro number. It shows a list of all the macros along with information on whether it already exists or not. The user assigned name will be shown after the number. If no name has been assigned the name will show as either “Used” or “Empty”. Clicking on a line makes that macro # the active current macro # which is used by most of the following menu entries.

### Run Macro: #(0-9)

This will run the currently selected macro number.

### Override Settings: Off | On

This is used to override the image setttings that are stored in the macro file with each BMP file. An example using it would be if it was recorded with frame hold time that needs to be changed to a different value. Setting this to on will then use the current frame time instead of the one saved in the macro file.

### Record Macro: Off | On

When set to on, the settings and displayed images will be appended to the currently selected macro number. It should be turned off when all the actions have been recorded. Use the delete command first if a sequence is to be recorded without appending.

### Repeat Count: 1

This value repeats the macro run.

### Repeat Delay: 0.0 S

This is the delay between each run of the macro when repeat is on.

### Information: #(0-9)

This will display some information about the currently selected macro.

* The macro name, “Empty”, “Used”, or a manually entered description
* Number of BMP files
* The total time for display
* The total number of horizontal pixels
* The total distance to walk to maintain the correct aspect ration

A long press exits the display.

Rotating the dial will show the list of all the BMP files in the macro. Rotating the dial again left or right will scroll through the list if it is longer than 7 files.

Clicking button 0 (top left on the TTGO) allows entry of the descriptive text for the current macro. A long press exits and saves the text. There is help on the screen for other button operations. The screen shows a list of available letters, numbers, and other symptoms. Rotating the dial selects a character and clicking the dial appends it to the end of the text. A long press on button 1 (bottom left on the TTGO) toggles between upper and lower case letters.

### Load: #(0-9)

This loads the settings in a macro file without running any image files contained in the file. If there are multiple settings the last one will be used.

### Save: #(0-9)

This saves the current settings in a macro file without saving any image files to run.

### Delete: #(0-9)

This erases the currently selected macro file. It is useful when a new sequence is to be recorded since the record action always appends new actions to the macro file.

### Delete: Macro JSON File

This is a file on the SD card that contains information about each macro. If it gets corrupted or something seems wrong just delete this file. It will automatically be recreated when the system boots. The times, sizes, and files are obtained from the macro files. The description text is contained only in the JSON file so it will be lost and must be entered again from the information menu.

## +Saved Settings

These settings are stored in the NVRAM section of the ESP32 and it is a useful way to set the defaults during boot time. The system settings are always automatically saved and loaded on startup. This means that LED strip, menu, and dial settings are effectively permanent, they will be saved and loaded automatically. Other settings can be loaded automatically by enabling the autoload switch.

There is a version number saved that will be compared when loading. A mismatch will force all settings to their default values. No message is displayed when this occurs.

### Autoload Saved

This flag causes the EEPROM (NVRAM) values to be loaded at boot time. If off, then the factory settings will be loaded instead. If factory settings are desired the button should be pressed during booting. This will ignore the setting of this flag.

### Save Current Settings

This saves the current settings. Built-in options settings are also saved. Note that MIW files do note save any of the built-in settings.

### Load Saved Settings

This manually loads the settings from EEPROM.

### Reset All Settings

This will reset everything to the factory values and erase the stored values in NVRAM.

### Format EEPROM

This clears the NVRAM and formats it for storing the values.

## +System Settings

Various system settings can be changed from this submenu. All these settings are automatically saved and are loaded automatically at boot time.

### +Display Settings

#### Display Rotation: 0 | 90 | 180 | 270

This rotates the display through the 4 positions so that it is readable when the wand is help upside down or sideways. This is particularly useful when using one LED strip and the wand should be held higher in the air. It is used used in conjunction with setting the image also upside down. Using a long press on button 0 is the easiest way to do this since it adjusts both the image and the display upside down (for 180 only) at the same time.

#### Display Brightness: 50%

This is the TFT display brightness from 1 to 100%. It is often desirable to lower it when working in darkness.

#### Display Dim Time: 0 S

When no buttons or dial rotations happen for this amount of time the display will dim to preserve power.

#### Display Dim: 30%

This is the value the display will dim to when the dim timer expires. This menu item is hidden when the dim time value is 0.

#### Sideways Scroll Settings

When lines are too long for the display, they will scroll sideways so the entire line can be seen. The speeds can be adjusted using the following menu items.

##### Sideways Scroll Speed: 25 mS

This is how fast the line scrolls to the left. Smaller numbers are faster, since it is actually the pause time per pixel.

##### Sideways Scroll Pause: 20

This is the number of scroll speed times to wait at the end of each line before switching direction and scrolling again. For example, when the scroll speed is 25 mS and the pause is 20 the scrolling will pause for 25 x 20 = 500 mS at end of the scrolling.

##### Sideways Scroll Reverse: 3x

This is a speed multiplier, well actually a divider of the time, that controls the reverse scroll speed. 3x means it will scroll three times faster in reverse than it does going forward.

#### Menu Choice: Color | \*

This controls the indicator on menus for the current selection. Color means that the background and foreground colors are reversed. The ‘\*’ choice leaves the text colors the same and adds a ‘\*’ to the beginning of the active menu line.

#### Text Color

This sets the text color to various allowed values. The default is blue.

#### Menu Wrap: No | Yes

When this is off scrolling of both files and menu items is pinned at the top and bottom of the list. If wrap is on, then rotation the dial to the right when at the last entry will go to the first entry and rotation left from the first entry to move to the last entry.

#### Preview Scroll: 120 px

This is the number of pixel columns that the preview display of an image is scrolled with each increment of the rotary dial. The default value is half the screen width.

### +Run Screen Settings

#### Show BMP on LCD: No | Yes

This option displays the bmp on the display along with the LED display. As each column is displayed on the LED strip the same column will be displayed on the TFT screen. This gives you some visual feedback as the image is processed. When off the %, progress bar and other values like repeats will be displayed.

#### Current File: Color | Normal

This controls the display of the top line in wand run mode, which displays the current image file or the current built-in pattern. There are two choices.

* Color, displays the name in black letters with color background
* Normal, displays the name in color with black background

#### Show More Files: Yes | No

In run mode the top line always shows the file to be displayed. When this flag is on the following lines on the display will show the next few files in the current folder.

#### Show Folder: Yes | No

The top line in run mode shows the current file to be run. If this flag is on it will include the folder path. It should be turned off if the folder path is too long.

#### Progress Bar: On | Off

When a file is running the second line of the TFT display can show a progress bar. This option is used to turn it on or off.

### +Dial & Button Settings

#### Dial: Normal | Reverse

This sets the direction of the dial that moves forward or backward through choices.

#### Dial Pulse Count: 1-5

It is sometimes desirable to reduce the sensitivity of the dial to rotation. Wearing gloves or shivering fingers is an example. This allows a counter to be set such that more than one click detent will be required to produce a dial motion. For example, setting this to 2 means that the dial must be moved two clicks before it would change the selection. Values from 1 to 5 are valid.

#### Rotate Speed: 30 mS

This value adjusts how fast the dial is allowed to send rotation clicks. It is the minimum time between clicks so it can be used to slow down fast rotation. The allowed values are from 5 to 500 Milliseconds.

#### Long Press Counts: 40

This value determines how long a long press is. Bigger numbers mean the button must be held down longer in order to be considered a long press.

#### Btn0 Long: DisplayRotation | LightBar

This is the action for a long press on the top left button. UpsideDown rotates the display and also shows the BMP reversed. LightBar runs the light bar function to use the wand as a light source. There will probably be more choices in the future.

#### Btn1 Long: LightBar | DisplayRotation

This is the action for a long press on the bottom left button. There will probably be more choices in the future.

#### Rotate Dial Type: Toggle | Pulse

There are two types (maybe more) of rotary dial encoding methods. Some pulse the A and B lines for each click of rotation while other just change to other state. The first kind always leaves A and B open and simply pulse A and B closed for a short period of time with each rotation click. This one is called “pulse”. The other kind changes between open and closed with each click. This is called “toggle”. The time relationship between the A and B contact closures determines the direction of rotation.

After a system reset to factory or the first time a new version of the software is loaded the software will try to determine which kind of rotary switch exists. If the rotary switch is the toggle kind, it might ask for the dial to be rotated one click in either direction. This happens when the dial is in the contacts open position since this is the normal position for the pulse dial type and the software can’t determine what the switch type is. Because the automatic detection works perfectly this menu option will rarely be needed.

If this option is set incorrectly the following symptoms will be noticed:

* + - 1. Each rotation click will move by two positions.
      2. It takes two rotation clicks to move one position.

If the system has either of these symptoms, then try the other option. Alternatively use the reset to factory and let the automatic switch detection fix it.

### Sleep Time: 0 Min

If this is set to a non-zero value, the MIW will go to sleep mode if nothing is run or selected for that many minutes.

### +Battery Settings

This menu has all the battery related settings.

**Battery Calibration:** The PCB is built with 10% tolerance components and battery voltages will differ slightly from different vendors. Because of this the most accurate battery charge indication will only be obtained after calibrating the high (100%) and low (0%) settings. The “Show Battery” menu entry is used to read the current battery level. For two cells this number will typically be in the 1000 to 1800 range.

Note that there are two main version of the PCB. One has an on-board power supply while the other requires an external power supply. The battery sensing line is separate for the latter one.

**Quick Battery Calibration**

* Fully charge the batteries
* Use “Show Battery” menu to obtain the high value number
* Put this number in “100% Battery”
* Multiple this number by 0.71 and put in “0% Battery”

**More Accurate 0% Battery Calibration**

For the most accurate 0% battery setting it will be necessary to use an adjustable voltage supply connected to the battery sense line (or the battery supply line on the on-board PCB). Set this voltage to 5.8 before connecting the power supply. You can also try lower voltages until the power supply (voltage regulator) does not supply 5V anymore. Do not go below 5.5V for two cells because a cell should never go below 2.75V. Next use “Read Battery” to obtain the value for the 0% setting.

#### Low Battery Sleep: Yes | No

When this is set to “Yes” the MIW will go to sleep when the current battery level value is below the 0% setting. The MIW will not turn on until the batteries are replaced or recharged.

#### Show Battery: Yes | No

This setting controls the display of the battery level on the main screen. When on it will use the bottom line to right of the display. It shows both a graphic value and text of the % value.

#### Read Battery

This will display the current value of the battery sense line on the PCB. It is useful to calibrate your batteries as described in the “Battery Settings” section above.

#### 100% Battery: high number

This is the full battery value. It should be set to the value from “Read Battery” obtained with fully charged batteries.

#### 0% Battery: low number

This is the lowest acceptable battery value. It is approximately 0.71 times the full value. LiIon batteries should never be discharged below 2.75 volts (5.5 v for two batteries), but the actual value may depend on the power supply used, which is often around 5.8 volts.

#### Battery Count: 1-4

This is set to the number of cells and will load default values for 100% and 0%. If set to 1, the power supply must of course be a boost regulator. Cells from 2 to 4 assume a buck regulator which lowers the output voltage to 5V.

### IP: 192.168.4.1

This is the address of the web page server built into the wand. It is very experimental and not complete yet. The only useful function is the ability to upload or download image files directly to the wand from a web browser on a phone or computer without removing the micro-SD card. More features will be added in the future, including complete control of the wand. To use it, first connect to the MIW….. network. The password is 12345678. Then point the browser to the IP address.

### Reset All Settings

This resets all the values to factory settings.

## Light Bar

This selection turns the Image Wand into an adjustable LED light source. All the LEDs are turned on. The menu can then be used to change the Hue, saturation, and brightness levels. The number of LEDs that are lit can also be changed, along with starting at the end or the middle. The maximum brightness is limited by the strip brightness that is set in the strip menu.

The default allows setting the brightness, hue and saturation, but it can also be changed to use RGB values or Kelvin. The default increment unit is 10 for each click of the dial but that can be adjusted for finer resolution.

Btn0 is used to cycle the increment that the dial uses. The values are 1, 10, 100, 256. Pressing Btn0 selects the next choice.

A long press of Btn0 and Btn1 will increment or decrement the current delay value by the increment value. The delay value is in mSec and is used to slow down the stepping when the dial is rotated. For example: if the increment is set to 10 and the dial is rotated right one click with the current Hue of 5, the hue will step from 5 to 15 with the delay after each step. This can provide a smooth change of the Hue value over a time value determined by the increment times the delay. All of the other settings behave the same as Hue. Experiment to see how they work!

A long press is used to turn the light bar off again.

## +Light Bar Settings

This is a menu that sets the default values for the light bar option.

### Allow Rollover

Allows values to rollover as the dial is rotated instead of stopping at the min and max.

### Color Mode: HSV | RGB | Kelvin

HSL or RBG or Kelvin can be chosen. The choice will affect some of the following menu lines.

### Hue: 0

Adjusts this value.

### Saturation: 255

Adjusts this value. 0 is no color.

### Brightness: 255

Adjusts this value. It is relative to the maximum set in the system LED menu.

### Red: 255

Allows the red value to be adjusted.

### Green: 255

Allows the green value to be adjusted.

### Blue: 255

Allows the blue value to be adjusted.

### Pixels: 288

How many pixels to be displayed. It is from 1 to the total number of LED pixels.

### Temp: Candle 1900K

Various Kelvin equivalent choices are available.

### From: Middle | End

There are two choices, **Middle**, and **End**. This selects where lit LED pixels start when the above pixel value is less than the full strip length. The end can be changed using the LED strip reverse setting described earlier.

## Reboot

This resets the system. Pressing btn0 and btn1 for a long press time will do the same.

## Sleep

This puts the TTGO into a low power mode. Pressing the button will wake it up again. It is useful to save the battery while not losing any of the current settings. Alternatively the settings can be saved and then restored after rebooting the wand.

# Built-In Patterns

There are several built-in pattern generators. Some of them have settings that can be adjusted from the entry that appears on the first menu when a particular built-in is selected. The available built-ins are listed below.

## Barber Pole

This creates a rolling red, white, and blue pattern. It will create diagonal patterns. The speed is controllable by setting the frame hold time.

## Beats

Colored bars moving up and down.

## Bouncy Balls

This uses physics calculations to simulate some colored bouncing balls. The number of balls can be set up to 8, each will have its own color. The speed can be changed using the same built-in menu. The frame hold time is not used. On an image it makes some interesting decaying inverted second order polynomial traces. Sorry about the math terms! Play with it.

## Checker Board

Alternating black and white boxes. The speed is adjustable using the built-in menu or the frame hold time.

## Confetti

Interesting color dots that appear and then fade out.

## Cylon Eye

This was inspired from the BattleStar Galactica movies, the evil Cylon eyes.

## Juggle

This shows some color bars that move up and down and cross over each other.

## Lines

This produces a series of stripes.

## Meteor

This looks kind of like a meteor moving from one end of the strip to the other.

## One Dot

Actually, this is four dots, red, green, blue and white. They move one at a time from one end to the other. It is probably mostly useful for testing the wand. That’s why it was written originally.

## Rainbow

The color, number of repeats, and color cycling can be controlled. It is even possible to add random sparkles to add a bit more interest. Try moving the wand in an arc for interesting rainbow-like patterns.

## Rainbow Pulse

This is rainbow that starts from the bottom, sweeps up, and then back down again until it is gone.

## Random Bars

This produces solid colors that alternate randomly. An option sets black in between each color bar. Waving the wand can make some interesting patterns in the air.

## Sine Trails

A little more math here traces a color blob using the sine function.

## Solid Color

This is probably one of the more useful patterns. It allows the LED strip to be used as a light source. The color can be controlled with the dial as well as the saturation and brightness. A setting allows the RGB values to be entered if that is desired. The brightness value is limited by the LED strip brightness setting from the main LED settings menu. So if more brightness is needed that value must be changed. The LED strip will stay on until a long press turns it off.

## Twinkle

A display of dots of various colors that change color randomly.

## Two Dots

This is like the One Dot, except that two dots are on the strip. They start at opposite ends and cross over in the middle. It was also written originally to test the code and the LED strip.

## Wedge

Creates a triangle type pattern.

# Menu structure

Here is a chart of the menus. Note that menus that are not applicable will not be displayed. For example, choosing Frame Time means that Fixed Time will not appear in the menu while choosing Fixed Time means that Frame Hold won’t appear. Some submenus are not shown in order to keep this chart smaller. One menu missing is the battery one.

# Construction

Yes, there are a few parts and a fair amount of wiring and soldering to do. If you aren’t comfortable soldering, find someone who is! The wiring harnesses are probably the most work to make, but they are essential in order to hook everything up. I will include a photo of the ones I make that should make it easier to duplicate. Looking at the schematic will help understanding what is connected to what. The 3D printed parts can be purchased from me if you can’t find anybody else to make them from the STL files. I print currently using PLA, so please don’t leave them in the sun, they will melt and deform if it gets too hot!

Also remember that the PCB makes building one of these much easier. There are two versions of the PCB, one that has a built-in 5V regulator and another that requires an external power supply. There are several versions of the 3D printer files for these cases, although the built-in power supply version is not complete yet and has not yet been uploaded. The external power supply version can supply more current for brighter LEDs. The internal one can supply about 1.5A but this is adequate for most night work. Using the wand as a light source might require more light, but building the wand is a little bit more complicated. Send me an email at martinnohr76 @ gmail.com if you want to order one. $40 + shipping for the one without the power supply and $45 + shipping for the one with the built-in power supply. Both of these include a programmed TTGO.

All of the screws are metric and should be available from a well-stocked hardware store. I got mine from Ace Hardware.

All of the electronic components and the aluminum channel are available from Amazon. They are likely also available from other vendors. I bought the aluminum shiny ones because I didn’t find the black anodized ones until later. Some people worry that the shiny aluminum will show in the final image. In practice I haven’t seen this, but I do plan to start using the black one after I finish using all the shiny ones I have in a box! I got the WS2812B LED strips from BangGood.com in China. Aliexpress.com also carries the WD2812B. Be aware that the shipping time from China can be quite long. Amazon is faster.

I am considering making a parts bag available with all the hardware parts needed. I buy them in quantity so it would be easy enough to put a bag together.

You can solder up a bunch of wires and connectors to connect everything inside the cpu/display box like I did for my first prototype. I have designed a printed circuit board holding all the parts and I can sell those for $50+shipping, it includes a programmed TTGO. For $30+shipping I can supply the PCB without the TTGO. There is still some wiring for the batteries and LED connectors, but it is much simpler when the dial, SD card reader, and TTGO are on a PCB.

The PCB version includes a level shifter to go from the ESP32 3.3 volt logic to the 5V specified for the WS2812B LED strips. If you build your own you can omit these level shifters. In testing we found that all our LED strips worked directly with 3.3V logic. There might be a rare LED strip that does not work however so we make no guarantees! Using a level shifter guarantees that the voltage levels meet the specifications.

## Parts List

Some changes have been made to this latest version. A new battery design uses two 18650 batteries and a voltage regulator. The USB chargers keep changing size and availability, so it was decided to not use them anymore.

### Electronic Parts

1. TTGO T1. <https://www.amazon.com/ICQUANZX-T-Display-Bluetooth-Development-Arduino/dp/B07VNG9D52/ref=sr_1_2?dchild=1&keywords=ttgo+t1&qid=1617379750&sr=8-2>
2. Optional TTGO with pre-soldered headers. <https://www.cytron.io/c-wifi/p-ttgo-t-display-esp32-1.14-display-module-presolder-header>
3. Micro SD card reader. <https://www.amazon.com/gp/product/B07BJ2P6X6/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1>
4. Voltage regulator. [Amazon.com: ( 6 Pcs ) MCIGICM LM2596 Buck Converter, DC to DC 3.0-40V to 1.5-35V Step Down Power Supply High Efficiency Voltage Regulator Module: Electronics](https://www.amazon.com/dp/B06XZ1DKF2?psc=1&ref=ppx_yo2_dt_b_product_details)
5. Rotating Switch. <https://www.amazon.com/gp/product/B07DM2YMT4/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1>
6. 5 pin, 4 pin, and 3 pin connectors. <https://www.amazon.com/gp/product/B07GGPQXFC/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1> <https://www.amazon.com/gp/product/B075K3M1TB/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1> <https://www.amazon.com/gp/product/B075K6N7DF/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1>
7. LED channel. <https://www.amazon.com/gp/product/B01LL2SLME/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1>
8. WS2812B LED strips. <https://www.amazon.com/gp/product/B07BKQZLDL/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1>

### 3D Printed Parts

1. Battery holder.
2. Base plate for LED strips.
3. Holder for wiring and LED connectors
4. Rotating handle base. (not ready yet for the TTGO version)
5. Rotating handle. (also not ready yet for the TTGO version)
6. Electronics box, this is designed for the PCB and snaps onto the handle.
7. Handle.
8. LED strip end protectors.

### Software and Libraries

I will make a compiled binary available on the github entry for this project if you don’t want to collect all these files and compile the code. It can be built with the Arduino IDE, but I personally prefer Microsoft Visual Studio Community version along with the Visual Micro extension for Arduino, which is a bargain at $19/year. Microsoft Visual Code can also be used with the added Arduino add-in.

The github entry has the schematic and other plans for the case.

<https://github.com/MartinNohr/MagicImageWand>

1. Arduino IDE, or Microsoft Visual Studio with Visual Micro, or VisualCode set up for TTGO esp32.
2. ESP32 support libraries for TTGO T1
3. Bodmer’s tft\_espi display library
4. FastLED library
5. SdFat by Bill Greiman

### Wiring Harnesses Without PCB

These are somewhat time consuming to make. Soldering skills are required. See pictures for what they look like.

1. Internal, for SD card reader, level shifter (optional but no guarantees), LED/Power, and rotating button.
2. Battery and LED’s.
3. Rotating button.