The NGT20 is an easy to use, 5v compatible propeller graphics device. It communicates simply with UART communication.

It will help you make your project by featuring:

- An Arduino shield-compatible interface
- Supports 5v and 3.3v interface
- Outputs both a VGA and NTSC/PAL
- Quick Sprite definition and display
- Easy to modify the NGT20's firmware
- Pins 1-8 of Propeller Chip are broken out
- VGA without costing tons of RAM, program space, and CPU time

Please let the table of contents help you find what you need to know.

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NMT Graphics Card NGT20 Overview

What can it do?

- The NGT20 produces 2 video outputs, VGA and NTSC
- Draws sprites
- Can do rainbow colors in foreground or background across tiles
- The firmware is open-source, so if you like you may modify your NGT20's firmware
- Can be used as an arduino shield, or plugged into a breadboard or female header
- Can be used without a secondary microcontroller or CPU, and instead as a propeller development or project board
- Pins 1-8 of the propeller are broken out for connection to other electronic devices

How does it work?

The NGT20 uses the **parallax propeller,** an 8-core microcontroller, clocked at 80 MHz. It is excellent for producing video signals, which is why it was chosen to make the NGT20. It runs at 3.3v, so it cannot directly connect to a 5v arduino, Z80 UART, or other 5v device, so the NGT20 uses a **voltage level shifter.** It **uses multiple cores** to generate video. It communicates with the host device with **115200 bps UART.** If you modify the firmware, or otherwise reprogram the NGT20, the way that it communicates can change.

What sets NGT20 apart from other graphics shields?

- Compatible with more host devices than just an arduino, anything capable of communicating on 115200 bps UART at 3.3v-5v will be compatible.
- Can draw rainbow text and sprites
- Supports the quick repeated drawing of sprites, as opposed to pixel-by-pixel draws
- Advanced arduino library for graphics and creating sprites at runtime
- Easily reprogrammed with a Prop Plug, as opposed to FPGA or CPLD versions
- Does not have to be used as an arduino shield or with a host device, but can be used as a propeller development platform (pins 1-8 are broken out and two video outputs are present)

In short, it is an **easy to use**, **NTSC/PAL output**, **expandable** and **reprogrammable** propeller graphics device.

How To Use The NGT20 With Arduino

Here begins directions on how to get off the ground with your new NGT20 board.

Connecting the NGT20 to your Arduino

A note on communication voltages:

- Since the serial output from the NGT20 is always 3.3v, regardless of what TX pin it's from, **3.3v-compatible devices will never have problems connecting to the NGT20 from voltage incompatibilities. This guarantees compatibility with 3.3v arduino boards.**

Stack the NGT20 onto the Arduino, with the VGA connector the opposite way of the arduino's USB and Barrel Jack connectors.

The NGT20 uses Arduino pins 6 and 9, 6 being the Arduino's RX and 9 being the TX. These pins are used by the Arduino Library, but it is important not to connect anything else to the pins. For interface with the NGT20 via arduino boards the NMT_GFX Arduino library can be used. It is best to have the library. Download it from GitHub here.

To initialize the NGT20 it the library must be set up first:

```
#include <NMT_GFX.h>
NMT_GFX ngt;
```

Easily done, simply includes NMT_GFX and creates an object to use. Now to actually initialize the NGT20:

```
ngt.begin();
```

ngt.begin properly resets the NGT20 so it is ready to receive commands. Now the NGT20 is initialized.

Colors and the NGT20

It is important to understand how colors work specifically for the NGT20. Please read this section to understand.

The NGT20's bitmap is divided into tiles. The default NGT20 firmware has 16 x tiles and 12 y tiles. Each tile has 16 columns and 16 rows. Each tile also has only 4 colors. These colors must be selected from one of 64 'color slots'. To make this concept easier to understand, here is an example:

Tile X is currently using color slot zero. There is text on the tile with the foreground using color 2 of the color slot's 4 colors. By changing color slot zero's color 2, that text's color changes for all tiles using that color slot, including tile X. If tile X's color slot is changed to slot 5 for instance, all the pixels in tile X will adopt their corresponding colors in slot 5.

Although this could seem a disadvantage, it can be useful for making a sprite change color as it moves or making rainbow text. It also allows the background of certain tiles to change, or text to change color at certain boundaries. There are both pros and cons to this approach to displaying colors.

List of arduino library functions

The NMT_GFX Arduino library is available here.

```
void NMT_GFX::print(x);
```
Print character or string x at the cursor and advance the cursor once.

```
void NMT_GFX::println(x);
```
Print the string or char x onto the screen and advance the cursor to the end of the string, then go to the next line.

```
void NMT_GFX::write_at(q, int x, int y);
```
Print the string or char q onto the screen where the upper left of the string is placed at (x, y). Does not affect cursor position.

`void NMT_GFX::set_cursor_pos(int x, int y);`
Set cursor position to (x, y). Note that unlike other functions, x and y are measured in characters, which are 6x13 pixels each.

`void NMT_GFX::line(int x1, int y1, int x2, int y2);`
Draw line from (x1, y1) to (x2, y2). (x2, y2) is new endpoint.

`void NMT_GFX::box(int x1, int y1, int x2, int y2);`
Make a square between (x1, y1) and (x2, y2)

`void NMT_GFX::fill_box(int x1, int y1, int x2, int y2);`
Make a solid square between (x1, y1) and (x2, y2)

`void NMT_GFX::fast(int x, int y);`
Makes a line between the endpoint of the last line or the last pixel, whichever occured last, and (x, y). New endpoint is (x, y)

`void NMT_GFX::clear();`
Fill every tile with color zero in its color slot.

`void NMT_GFX::fill(byte color);`
Fill every tile with color in its color slot.

`void NMT_GFX::set_color(byte color);`
Make next draws use color.

`void NMT_GFX::pixel(int x, int y);`
Draw pixel at (x, y)

`byte NMT_GFX::x_tiles();`
Returns number of x tiles. Multiply this by 16 to get number of columns.

`byte NMT_GFX::y_tiles();`
Returns number of y tiles. Multiply this by 16 to get number of rows.

`char* NMT_GFX::get_card_ver();`
Returns string for device. For an NGT20 it should be “NGT20”. Newer or older versions may say something different, like “NGT35”.

`void NMT_GFX::block_color(byte slot, byte color);`
Set color (slot>>6) in slot (slot&63) to the argument ‘color’.

`void NMT_GFX::tile_color(int tile, byte slot);`
Make a tile use a specific color slot.

```
byte NMT_GFX::make_color(byte r, byte g, byte b);
```

Returns a color for use in `NMT_GFX::block_color()` using RGB color input.

There are code examples for many of these in the NMT_GFX library, accessible through the Arduino IDE.

Creating, loading, and displaying a sprite definition

All examples here are written in C++ for the Arduino. They use the NMT_GFX Arduino library available here.

All the code I present here will be in the Arduino function "setup", except for variable declarations.

This example uses NMT_GFX's Sprite class. It is a simple and easy to use class that only requires the definition of the sprite size and center, some RAM to use, and some initialization. First some memory must be allocated for the Sprite:

```
Byte image[52];
```

This is enough space for an 8x24 sprite. 4 bytes are used for parameters and 48 bytes times 4 pixels/byte = 192 pixels. X length has to be a multiple of eight in RAM, so 192/8 = 24 y pixels. Ok, here is where the sprite is defined:

```
Sprite sprite;
```

No fancy constructor, just the definition. It is initialized by these lines:

```
// tell sprite where to store it's data
sprite.binary_image=(byte*)image;
// tell sprite how big it is
sprite.set_size(8,24);
// set the center at 4,4 pixels
sprite.set_center(4,4);
```

The sprite is told the location of its memory, its size, and its center. Now it is ready to be written.

The writes are done with function calls to Sprite::fill() and Sprite::pixel()

```
// fill sprite
sprite.fill(2);
// draw some pixels
sprite.pixel(3,3,0);
... And more writes ...
```

sprite.fill(2) makes all pixels in the sprite color 2 of whichever color slot that pixel occupies. The color slot occupied is the pixel's tile's color slot. To understand how these colors work see Colors and the NGT20.

sprite.pixel(3, 3, 0) makes the pixel at (3, 3) color 0 of its color slot.

Once all writes are done on the sprite it MUST be uploaded to the NGT20:

```
sprite.upload();
```

Easy. Now we can put it across the screen a ton of times:

```
// Display sprite at 50,60 at a 0 degree angle
sprite.display(50,60,0);
sprite.display(20,60,0);
sprite.display(60,60,0);
```

These lines display the same image 3 times, each time minimal exchange happens between the NGT20 and the Arduino, as opposed to slowly and painfully writing raw pixels and boxes to the screen, in a repetitive inefficient process.

sprite.display()'s 3rd argument specifies the orientation of the sprite. 0 is 0 degrees, 1 is 90 degrees, 2 is upside down, and 3 is 270 degrees.

Now things get even cooler though. The array of bytes given to the Sprite is an image and can be saved somewhere and reloaded later. To reload a Sprite from a raw memory/binary image simply do this:

```
sprite.binary_image=your_saved_image_as_byte_array
```

Now you can save a sprite in eeprom, on an SD card, and more, then reload it later.

Hope this helps you create a sprite.

Troubleshooting

NGT20 won't display anything. Green light stays on and TV/Monitor gets signal.

Most likely the MODE_SW is switched the wrong way. It is located next to the VGA connector. It should be switched toward the arduino header. If it isn't then the arduino will not connect to the NGT20. The MODE_SW is used for debugging and programming the NGT20.

NGT20 was working, then green light turned solid and it stopped responding.

This will happen if a bad sprite is displayed. Simply press the red button on the NGT20 to hard reset it.

How To Use The NGT20 - not Arduino-compatible

Here begins directions on how to get off the ground with your new NGT20 board if you aren't using an arduino.

Connecting the NGT20 to your host device

A note on communication voltages:

- Since the serial output from the NGT20 is always 3.3v, regardless of what TX pin it's from, **3.3v-compatible devices will never have problems connecting to the NGT20 from voltage incompatibilities**

The NGT20 has 4 headers where communication with a host is possible.

Arduino Shield Interface

Does not require an arduino board, but requires a board that has arduino headers.

This is a 5v-compatible interface connecting pins 6 and 9 of the Arduino to pins 39 and 40 of the Propeller chip, respectively. You will need to open serial where pins 6 and 9 would be on an arduino, pin 6 being your RX and pin 9 being your TX, at 115200 bps.

GFX_PORT Header

The GFX_PORT is a more direct and efficient way of connecting a NGT20 to an FPGA, PIC, Z80 Computer, or non-UNO-Rev3 compatible device. It only requires a ground supply, 3.3v, and 2 connections for UART. The UART pins are 5v-compatible, but will not harm 3.3v only devices.

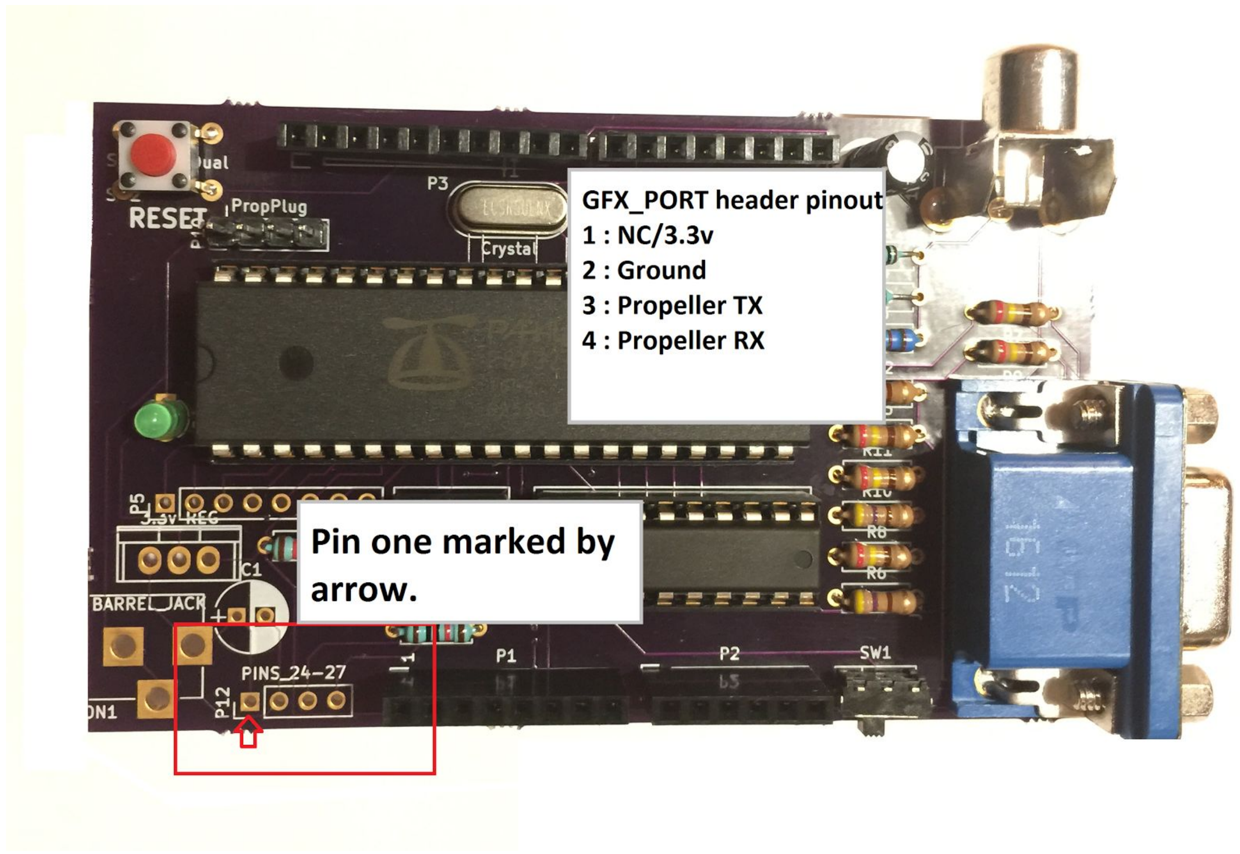
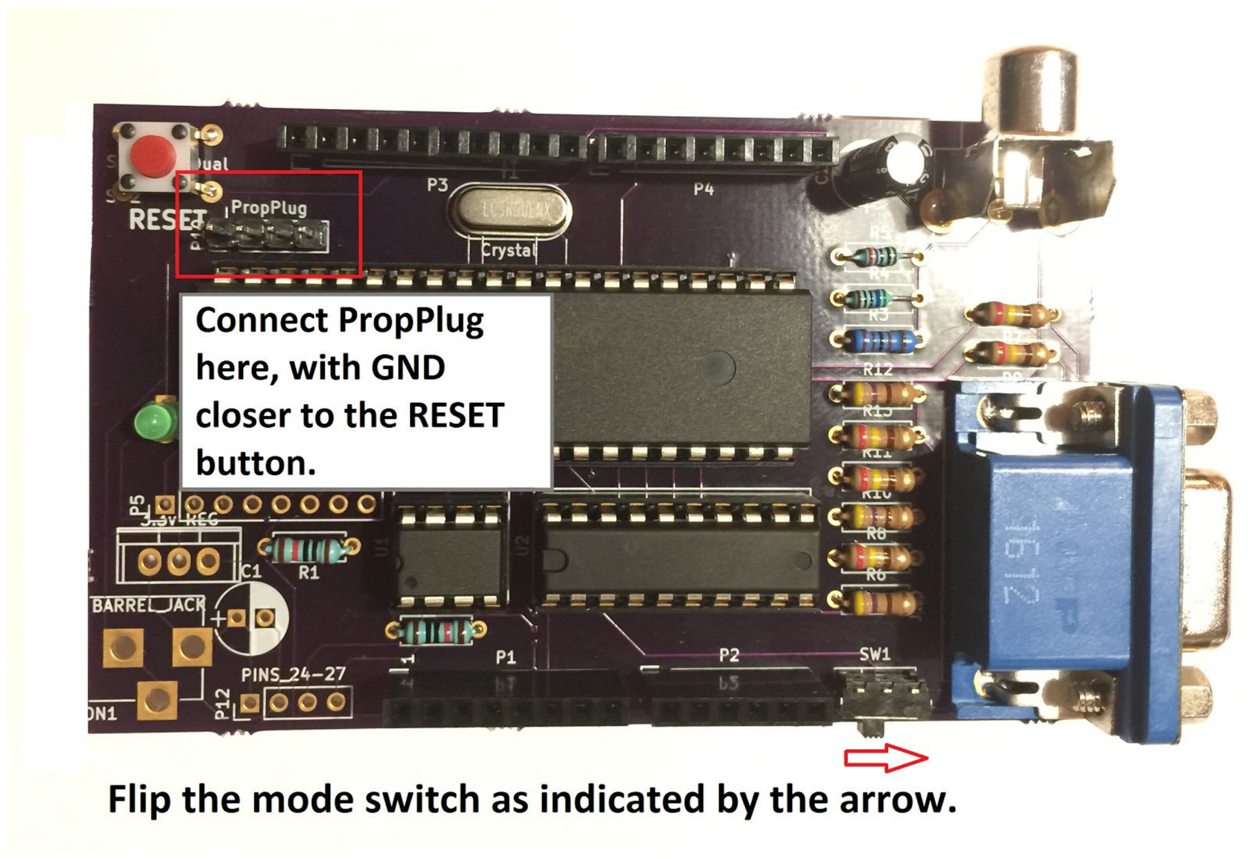


Figure 1: This is where you can find the GFX_PORT. It also shows the connector's pins and their descriptions.

Be sure to power the NGT20's 3.3v supply via the arduino header labeled 'P1' on the PCB. That header's pin 4 needs to be connected to 3.3v.

Prop Plug Communication

It is possible to communicate with the NGT20 through the Prop Plug connector. This is best for testing and programming the NGT20. **This is extremely useful for testing custom firmware.** You can both program and communicate with the NGT20 at the same time. Do note that in order to do this you will need to connect the NGT20 to an external power supply via the on-board barrel jack. It accepts input voltages between 3.3v and 9v DC only. You will also require a Prop Plug or other USB to serial converter. If you do not use a Prop Plug, then I cannot guarantee that you will be able to program the NGT20 from your computer. **If you do not use a Prop Plug make sure you use a 3.3v compatible USB to Serial converter!** The Prop Plug port is NOT 5v compatible. Connect your Prop Plug or Serial converter between your computer and your NGT20. The Prop Plug port is located as so on the NGT20:


Connect PropPlug here, with GND closer to the RESET button.
Flip the mode switch as indicated by the arrow.
RESET
PropPlug
Crystal
P3
P4
P1
P2
SW1
BARREL_JACK
PINS_24-27
3.3v REG
C1
R1

After connecting the Prop Plug be sure to either remove chip U2 or flip the MODE_SW. Note that in order to enable 5v communication again this must be undone.

The NGT20 will be connected to the computer. Now you may use a serial terminal to communicate directly, Python to have your computer automatically communicate with the NGT20, or the Propeller Tool to program the NGT20. **Various IDEs for propeller are available from parallax here.**

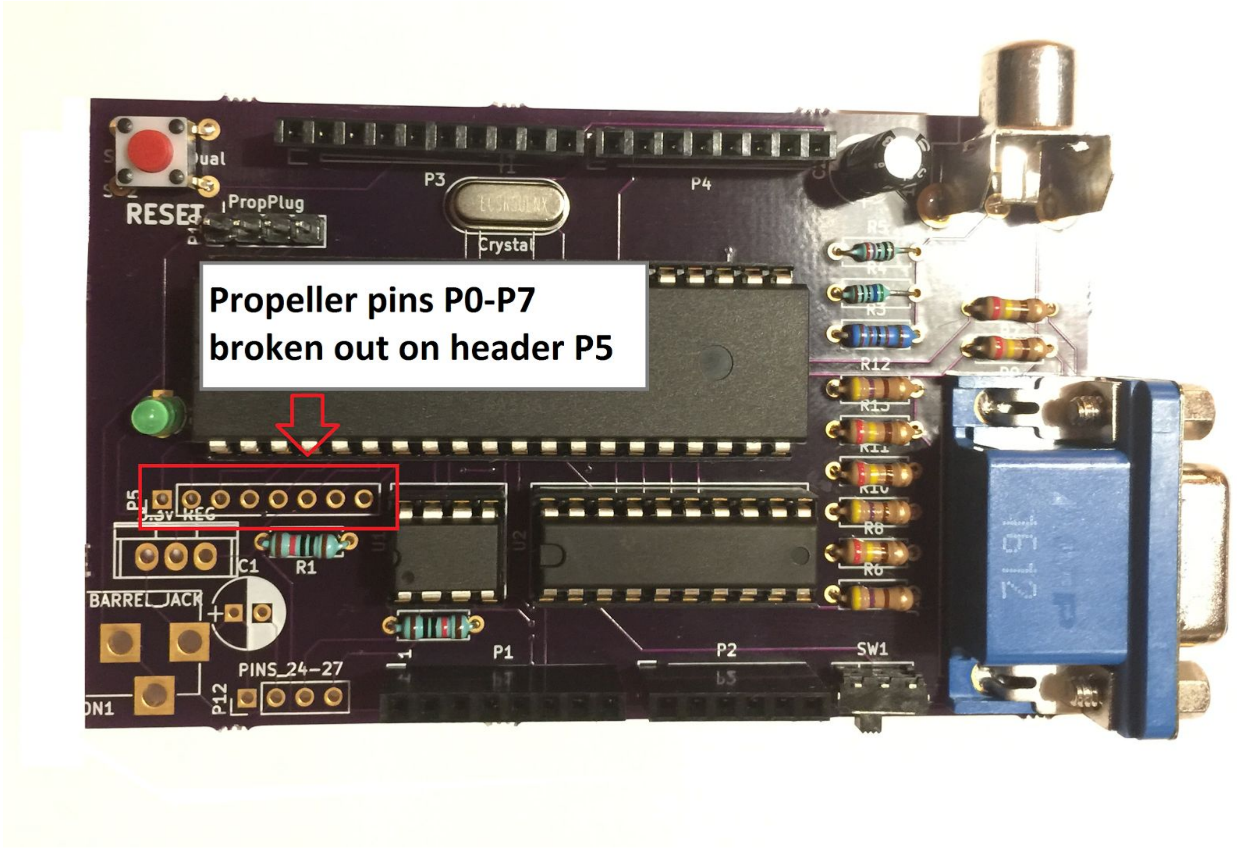
Using the broken out pins 1 - 8 of the propeller

NOTE: Usage of these pins must be done via modification to the NGT20 firmware. These pins are NOT 5v compatible.

Usage of these pins for communication is more difficult - but very flexible - due to the requirement of firmware modification or the complete reprogramming of the NGT20. There are too many directions to go as to being able to use these pins, so here listed are examples of what can be done with them:

- Extra IO for sensors or output devices
- Adding keyboard functionality
- Communication with host device using more than 2 pins
- Incredible possibilities...

The simplest way to use them is to move the UART pins of the NGT20 to two of these via firmware editing.
Here is where they are on the board:



Colors and the NGT20

Please read this for proper understanding of how colors work for the NGT20.

The NGT20's bitmap is divided into tiles. The default NGT20 firmware has 16 x tiles and 12 y tiles. Each tile has 16 columns and 16 rows. Each tile also has only 4 colors. These colors must be selected from one of 64 'color slots'. To make this concept easier to understand, here is an example:

Tile X is currently using color slot zero. There is text on the tile with the foreground using color 2 of the color slot's 4 colors. By changing color slot zero's color 2, that text's color changes for all tiles using that color slot, including tile X. If tile X's color slot is changed to slot 5 for instance, all the pixels in tile X will adopt their corresponding colors in slot 5.

Although this could seem a disadvantage, it can be useful for making a sprite change color as it moves or making rainbow text. It also allows the background of certain tiles to change, or text to change color at certain boundaries. There are both pros and cons to this approach to displaying colors.

Technical Specifications

Communication protocol of the NGT20

The NGT20 accepts commands on the UART port and interprets them. It then returns a result on the UART. Some commands take arguments to give the NGT20 more information about what it is being told to do.
Note that:

- All commands are sent in sequences of bytes
- String arguments are NOT zero terminated, but CR-terminated.
- Any unlisted command IDs have no effect on the NGT20. For a more advanced device, the effect will be different and that device's datasheet should be referenced.

To run a command on the NGT20 first a the command ID must be sent, then its arguments. The arguments are in the same order as specified in the table under "Commands At A Glance".

Argument Data Types

Different arguments are different data types.
Data types include:

- BYTE
- WORD (2 bytes)
- STRING (any number of bytes, CR-terminated)

Any command with arguments will accept more data after the sending of the command ID. For each argument data must be supplied, the length of each argument depending on data type. Refer to the bulleted list above, and remember to CR-terminate all STRINGs.

Refer to the table below for the arguments of each command.

Commands At A Glance

Command ID	Command Description	Arguments
13	Newline	None
32	Get device type (CR-terminated)	None
48	Reset NGT20	None

49	Clear Screen	None
50	Set Cursor Pos	BYTE x, BYTE y
51	Write string	STRING str, BYTE 0x0D
52	Draw line	WORD x1, WORD y1, WORD x2, WORD y2
53	Fill Screen with color	None
54	Fill box	WORD x1, WORD y1, WORD x2, WORD y2
55	Write string at position	WORD x, WORD y, STRING str, BYTE 0x0D
56	Write pixel	WORD x, WORD y
57	Set Color	BYTE color
61	Change color slot	BYTE slot, BYTE color
62	Draw sprite	WORD x, WORD y, BYTE rotation, WORD address
63	Write RAM	WORD address, BYTE data
64	Get output type	None
66	Set tile color	WORD tile, BYTE slot
67	Fast line	WORD x, WORD y

Commands - In Depth Descriptions

Please refer to the table above for information on command arguments.

Command 13 : New Line

Will advance the cursor downward 1 character. If the cursor leaves the screen then the entire screen is scrolled up. This affects all pixels on the screen, so be careful or use this to your advantage.

Command 32 : Get Device Type

Will send a null terminated string indicating the device type. For the NGT20 it would literally be “NGT20”, then a NULL.

Command 48 : Reset

Will completely reboot the NGT20, all pixels, sprites, and colors will be lost. Equivalent to pressing the reset button, except Command 48 requires no mechanical action.

Command 49 : Clear screen

Sets cursor to top left and makes every pixel use it's tile's zeroth color. Note that this means pixels in different tiles may have different colors due to the tiles having a modified tile colors. Use Command 61 to change a color set's colors and Command 66 to change a tile's color set.

Command 50 : Set Cursor Pos

Set cursor position for Command 51. Measured in characters. Each character is 6 pixels wide and 13 pixels tall.

Command 51 : Write string at cursor position

Writes a carriage-return terminated string on the screen and advances the cursor to after the string's end. If the string goes past the end of the screen it loops back on the other side. If it continues below the screen's lower edge then the screen scrolls up, including all pixels, and the string continues writing. BE SURE THE STRING IS CR-TERMINATED!

Command 52 : Draw Line

Draws a line from (x1, y1) to (x2, y2).

Command 53 : Fill Screen with color

Fill screen with color. Note that color is NOT an RGB color, but a number from 0-3 referring to tile color. To change the color slot of a tile or colors in a color slot use commands 61 and 66.

Command 54 : Fill box

Fill box with opposite edges at (x1,y1) and (x2, y2)

Command 55 : Write string at position

Writes string at (x, y)
Does not change cursor position. X and y are in pixels, not characters. Also note that the justification of the text places the upper left of the string at (x, y).

Command 56 : Write Pixel

Draws a pixel at (x, y)

Command 57 : Set Color

Set color for next draw/text commands. Note that color is NOT an RGB color, but a number from 0-3 referring to tile color. To change the color slot of a tile or colors in a color slot use commands 61 and 66. Does not apply to command 49 (Clear Screen)

Command 61 : Change color slot

There are 64 color slots. The lower 6 bits of the slot argument define which color slot. The upper 2 bits select one of 4 of the 1-byte color definitions for that slot.

Command 62 :Draw sprite

Draws a sprite at (x, y). Rotation is 0-3, where 0 is no rotation, 1 is 90 degrees, 2 is 180, and 3 is 270. Sprite is the offset of a sprite definition written to the NGT20's RAM. For instructions on creating a sprite definition, loading it, and displaying it refer here.

Command 63 : Write RAM

The NGT20 has 2KiB of RAM that can be written to store sprites. You could store about 170 8x4 pixel sprites with this space. Command 63 writes one byte of this memory for loading sprites to the NGT20. For instructions on creating a sprite definition, loading it, and displaying it refer here.

Command 64 : Get output type

This command returns data about your NGT20 depending on its firmware. The command sends back 3 bytes of data. The first byte is the number of x tiles. Every X tile has 16 columns. The second byte is the number of y tiles. Every Y tile has 16 rows.

The last byte should be 'D' if the NGT20 has the default firmware. If the firmware does not support NTSC output the char will be 'V'. If it only supports NTSC the char will be 'N'.

Command 66 : Set tile color

Sets specified tile to use specified color slot.

Command 67 : Fast line

Excellent for drawing lines fast - takes about half the time of a normal line draw.

If a line was drawn last then it's endpoint becomes the fast line's starting point. If it was a pixel then that pixel becomes the starting point. The fast line's endpoint is (x, y).