

# ESP32-CAM GRBL CNC Controller Documentation

## Overview

This firmware transforms an ESP32-CAM module into a powerful CNC controller with integrated camera capabilities. The system communicates with an Arduino running GRBL firmware over serial communication, providing a complete web-based interface for machine control, camera monitoring, and automated scanning operations.

## System Architecture

### Hardware Components

- **ESP32-CAM Module:** Primary controller with integrated camera
- **Arduino Board** (Uno/Nano/Mega): Running GRBL firmware for CNC control
- **SD Card:** For storing captured images and scan data
- **WiFi Network:** For remote access and control

### Communication Flow

Web Browser ↔ ESP32-CAM Web Server (Port 80)

↓

ESP32-CAM Stream Server (Port 81)

↓

ESP32-CAM ↔ Arduino (UART Serial @ 115200 baud)

↓

GRBL Firmware

↓

Stepper Motors/Drivers

## Setup Instructions

### Prerequisites

- ESP32-CAM module with camera
- Arduino board with GRBL firmware installed
- SD card formatted as FAT32

- WiFi network credentials

## Configuration (Before Upload)

Edit these parameters in the code (if needed):

```
// HTTP Server Ports
const uint16_t HTTP_PORT = 80;    // Web interface
const uint16_t STREAM_PORT = 81;  // Camera stream

// GRBL Communication
const uint32_t GRBL_BAUD = 115200; // GRBL baud rate
```

## Wifi Setup

Use Serial terminal to connect to wifi, steps are as follow:

- Send **menu** for Main Menu

```
=====
Main Menu
=====
1. WiFi Configuration
  - Configure WiFi networks
2. Credentials Management
  - Manage stored networks
3. System Status
  - Show system information
4. Exit Menu
  - Return to command mode
=====
Timeout: 179 seconds
Press '0' to exit menu
=====
```

- Select option 1

```
Select option (1-4): 1

=====
WiFi Configuration
=====
1. Scan Networks
  - Scan for available networks
2. Connect to Network
  - Connect to WiFi network
3. Auto Connect
  - Auto-connect to stored networks
4. Check Connection
  - Check current WiFi status
5. Back to Main Menu
  - Return to main menu
=====
Timeout: 179 seconds
Press '0' to exit menu
=====
```

- Select 1 to scan networks

```
Select option (1-5): 1

=====
WiFi Network Scan
=====
Available networks:
=====
1. HUAWEI Y5 2017      RSSI: -62  [SECURED]
=====
```

- Select your network, add password

```
Select network to connect to (0 to cancel)
> 1

=====
Connect to WiFi Network
=====

Enter WiFi password (leave blank for open network)
> *****

Connecting to HUAWEI Y5 2017...
Attempting to connect to: HUAWEI Y5 2017
✓ Connected to HUAWEI Y5 2017 successfully
IP Address: 192.168.43.99
✓ Connection successful!
```

## Hardware Connections

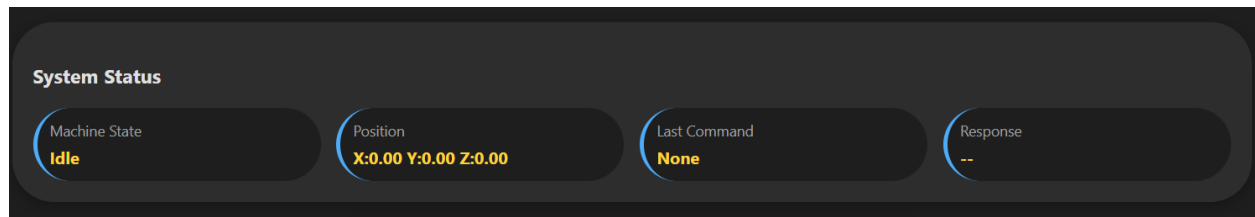
Connect ESP32-CAM to Arduino GRBL:

- ESP32 TX (GPIO1) → Arduino RX
- ESP32 RX (GPIO3) → Arduino TX
- GND → GND

## Web Interface Documentation

### Main Controls Tab

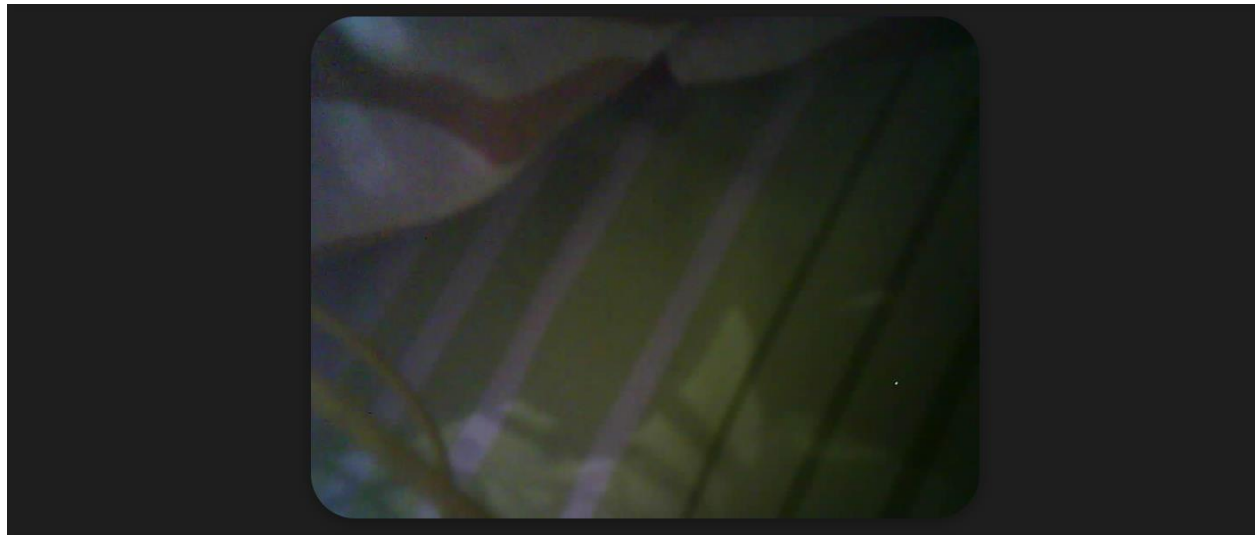
### System Status Section



Displays real-time machine information:

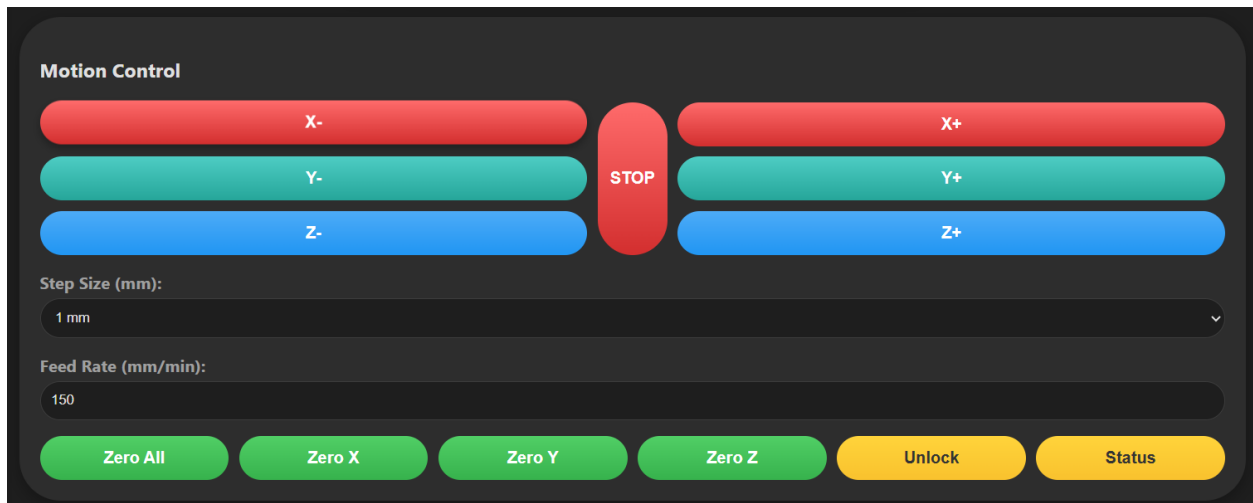
- **Machine State:** Idle, Run, Hold, Alarm, etc.
- **Position:** Current coordinates (X, Y, Z) in work position
- **Last Command:** Most recent command sent to GRBL
- **Response:** GRBL's response to commands

### Camera Feed



- Live MJPEG stream from ESP32-CAM camera
- Automatically loads from [http://\[esp-ip\]:81/stream](http://[esp-ip]:81/stream)
- Resolution and quality adjustable via Camera Settings tab

### Motion Control



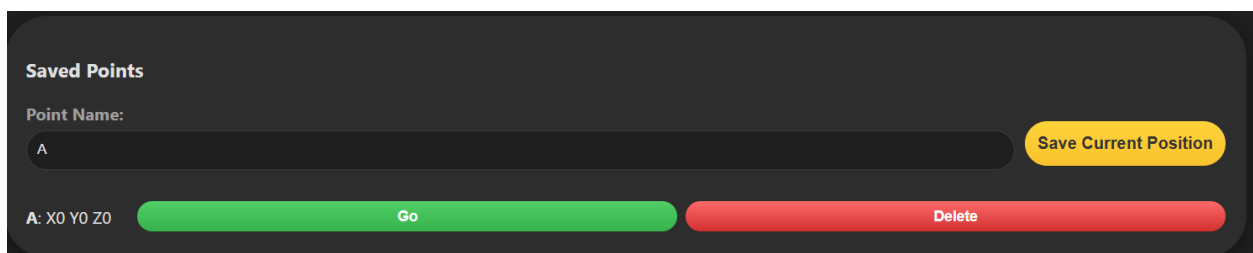
### Jogging Controls:

- Axis buttons (X+, X-, Y+, Y-, Z+, Z-) for manual movement
- **Step Size:** Configurable movement increments (0.1mm to 100mm)
- **Feed Rate:** Movement speed in mm/min (10-5000)

### Quick Actions:

- **Zero All:** Sets all axes to zero position (G10 L20 P0 X0 Y0 Z0)
- **Zero X/Y/Z:** Sets individual axis to zero
- **Unlock:** Removes GRBL alarm state (\$X)
- **Status:** Refreshes machine status

### Saved Points



- **Save Current Position:** Stores current coordinates with custom name
- **Go To Point:** Moves machine to saved position
- **Delete Point:** Removes saved position
- Points persist across sessions and are stored in ESP32 memory

## Spatial Scan

The screenshot shows a dark-themed control panel for a spatial scan. At the top, the title 'Spatial Scan' is displayed. Below it, there are five input fields for defining the scan area: 'X Start (mm):' with a value of 0, 'X End (mm):' with a value of 100, 'Y Start (mm):' with a value of 0, 'Y End (mm):' with a value of 10, and 'Step Size (mm):' with a value of 5. Below these fields is a 'Scan Feed Rate (mm/min):' field with a value of 150. At the bottom, there are two large buttons: 'Start Scan' and 'Stop/Resume Scan'. A progress bar is located below the buttons, and the word 'Ready' is displayed in yellow text at the bottom center.

Automated grid scanning with camera capture:

- **X/Y Start/End:** Define scan area boundaries
- **Step Size:** Distance between capture points
- **Scan Feed Rate:** Movement speed during scanning
- **Progress Bar:** Visual scan progress indicator
- **Stop/Resume:** Pause and resume scanning operations

Images are saved to SD card in /scan\_[number] folders with sequential numbering.

## Camera Settings Tab

The screenshot shows a dark-themed control panel for camera settings. The title 'Camera Settings' is at the top. Below it, there are five settings sections: 'Resolution' with a dropdown menu showing 'SVGA (800x600)', 'Quality' with a slider set to 10, 'Brightness' with a slider set to 0, 'Contrast' with a slider set to 0, and 'Flip Options' with two buttons: 'H-Flip' and 'V-Flip'.

## Resolution

- QVGA (320×240)

- VGA (640×480)
- SVGA (800×600) - Default
- XGA (1024×768)
- HD (1280×720)
- UXGA (1600×1200)

### Quality

- Adjustable JPEG quality (5-63)
- Lower values = better quality, larger files
- Higher values = worse quality, smaller files

### Brightness & Contrast

- Range: -2 to +2
- Real-time adjustment of camera sensor parameters

### Flip Options

- **H-Flip:** Horizontal mirror
- **V-Flip:** Vertical flip

### Motion Settings Tab

**Motion Settings**

**Default Feed Rates**

Default Feed Rate (mm/min):

150

**Step Increments**

Small Step (mm):

0.1

Large Step (mm):

10

### Default Feed Rates

- Sets default movement speed for all operations
- Range: 10-5000 mm/min

### Step Increments

- **Small Step:** Fine movement adjustment (0.01-1mm)
- **Large Step:** Coarse movement adjustment (1-100mm)

## Scan Settings Tab

The screenshot shows a 'Scan Settings' interface with two main panels. The 'Scan Parameters' panel on the left contains two input fields: 'Default Scan Feed Rate (mm/min):' with a value of 150, and 'Default Step Size (mm):' with a value of 5. The 'Scan Limits' panel on the right contains two input fields: 'Max Scan Area X (mm):' with a value of 200, and 'Max Scan Area Y (mm):' with a value of 200.

## Scan Parameters

- **Default Scan Feed Rate:** Preset speed for scanning operations
- **Default Step Size:** Preset distance between scan points

## Scan Limits

- **Max Scan Area X/Y:** Defines maximum allowable scan dimensions
- Prevents accidental large movements

## System Info Tab

The screenshot shows a 'System Information' interface with a grid of 12 circular widgets, each displaying a system metric. The metrics are: Chip Model (ESP32-D0WD-V3), Chip Revision (301), CPU Frequency (240 MHz), Reset Reason (1), WiFi SSID (HUAWEI Y5 2017), IP Address (192.168.43.99), Signal Strength (-60), Uptime (0d 0h 6m 52s), RAM Usage (61 %), Free Heap (120.6 KB), Min Free Ever (94.3 KB), and Max Alloc Block (76.0 KB). The Flash Size (4 MB) and Flash Speed (80 MHz) are also listed but not in a widget.

## Hardware Information

- **Chip Model:** ESP32 variant identifier
- **Chip Revision:** Silicon revision
- **CPU Frequency:** Current processor speed



- **Reset Reason:** Boot cause analysis

### Network Information

- **WiFi SSID:** Connected network name
- **IP Address:** ESP32's assigned IP
- **Signal Strength:** RSSI in dBm
- **Uptime:** System runtime duration

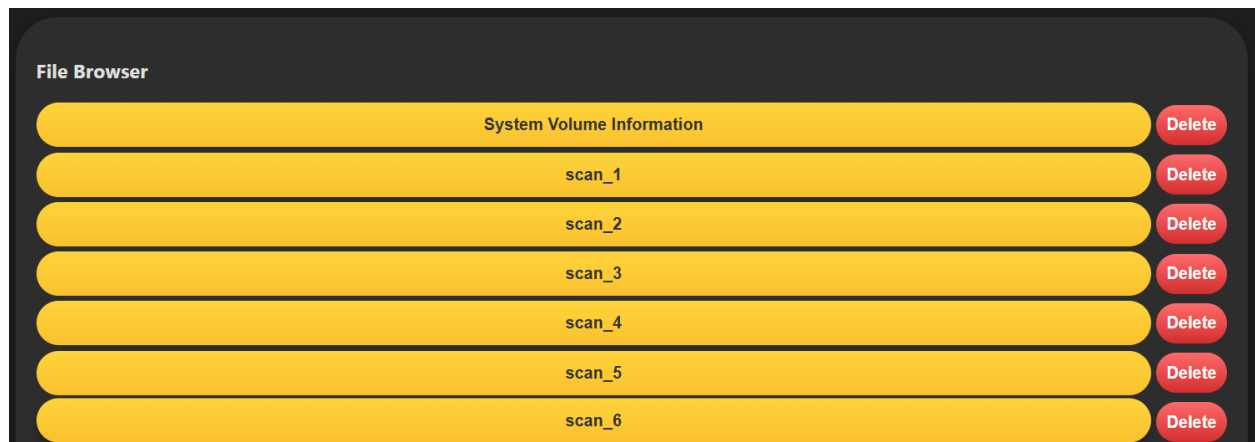
### Memory & Performance

- **RAM Usage:** Current heap utilization percentage
- **Free Heap:** Available memory in KB
- **Min Free Ever:** Lowest memory point since boot
- **Max Alloc Block:** Largest contiguous free memory block

### Storage

- **Flash Size:** Total onboard flash memory
- **Flash Speed:** Memory clock frequency

### File Browser Tab



### Directory Navigation

- Browse scan folders (/scan\_1, /scan\_2, etc.)
- Navigate through folder hierarchy
- Parent directory access

## File Management

- **Download:** Retrieve captured images
- **Delete Folder:** Remove entire scan directories with confirmation
- Files displayed with visual buttons for easy access

## API Documentation

### Core GRBL Commands

#### Send Command to GRBL

GET /cmd?c=[command]

##### Parameters:

- c: URL-encoded GRBL command (required)

##### Example:

```
curl "http://192.168.1.100/cmd?c=G0%20X10%20Y20%20F500"
```

**Response:** ok or error message

#### Get Machine Status

GET /status

##### Response (JSON):

```
{  
  "state": "Idle",  
  "position": "X:10.00 Y:20.00 Z:0.00"  
}
```

##### Example:

```
curl http://192.168.1.100/status
```

### Camera Control APIs

#### Set Camera Parameters

GET /camera?[parameter]=[value]

##### Parameters:

- res: Resolution (3=QVGA, 5=VGA, 6=SVGA, 7=XGA, 8=HD, 10=UXGA)
- quality: JPEG quality (5-63)

- brightness: Brightness level (-2 to +2)
- contrast: Contrast level (-2 to +2)
- hmirror: Horizontal mirror (0=off, 1=on)
- vflip: Vertical flip (0=off, 1=on)

### Examples:

```
# Set resolution to VGA
curl "http://192.168.1.100/camera?res=5"

# Set brightness to +1
curl "http://192.168.1.100/camera?brightness=1"

# Enable horizontal flip
curl "http://192.168.1.100/camera?hmirror=1"
```

## Spatial Scan APIs

### Start Scan

GET

/startscan?xstart=[value]&xend=[value]&ystart=[value]&yend=[value]&step=[value]&feed=[value]

### Parameters:

- xstart, xend: X-axis scan boundaries (mm)
- ystart, yend: Y-axis scan boundaries (mm)
- step: Distance between points (mm)
- feed: Scan movement speed (mm/min, optional)

### Example:

```
curl
"http://192.168.1.100/startscan?xstart=0&xend=100&ystart=0&yend=50&step=5&feed=150"
```

**Response:** OK or error message

### Stop/Resume Scan

GET /stopscan

GET /resumescan

## Examples:

```
# Pause scan
curl http://192.168.1.100/stopscan

# Resume paused scan
curl http://192.168.1.100/resumescan
```

## Get Scan Status

GET /scanstatus

## Response (JSON):

```
{
  "status": "Scanning...",
  "progress": 45
}
```

## Example:

```
curl http://192.168.1.100/scanstatus
```

## System Information APIs

### Get IP Address

GET /ip

## Example:

```
curl http://192.168.1.100/ip
```

**Response:** 192.168.1.100

### Get Detailed System Info

GET /systeminfo

**Response (JSON):** Comprehensive system metrics including memory, storage, network, and hardware details.

## Example:

```
curl http://192.168.1.100/systeminfo
```

## File Management APIs

### List Files in Directory

GET /files?dir=[path]

## Parameters:

- dir: Directory path (optional, defaults to root)

#### Response (JSON):

```
{
  "parent": "/",
  "folders": ["/scan_1", "/scan_2"],
  "files": ["/scan_1/img_00001.jpg"]
}
```

#### Example:

```
curl "http://192.168.1.100/files?dir=/scan_1"
```

#### Download File

GET /download?file=[path]

#### Parameters:

- file: Full path to file (must start with /scan\_ and end with .jpg)

#### Example:

```
curl -O "http://192.168.1.100/download?file=/scan_1/img_00001.jpg"
```

#### Delete Folder

GET /deletefolder?folder=[path]

#### Parameters:

- folder: Full folder path (must start with /scan\_)

#### Example:

```
curl "http://192.168.1.100/deletefolder?folder=/scan_1"
```

**Response:** Folder deleted or error message

### Position Management APIs

#### Save Current Position

GET /savepoint?name=[name]

#### Parameters:

- name: Position name (required)

#### Example:

```
curl "http://192.168.1.100/savepoint?name=Home_Position"
```

#### Get Saved Points

GET /getpoints

### Response (JSON):

```
[
  {
    "name": "Home_Position",
    "x": 0.000,
    "y": 0.000,
    "z": 0.000
  }
]
```

### Example:

```
curl http://192.168.1.100/getpoints
```

### Delete Saved Point

GET /deletepoint?name=[name]

#### Parameters:

- name: Position name to delete (required)

### Example:

```
curl "http://192.168.1.100/deletepoint?name=Home_Position"
```

### Move to Saved Point

GET /gotopoint?name=[name]

#### Parameters:

- name: Position name to move to (required)

### Example:

```
curl "http://192.168.1.100/gotopoint?name=Home_Position"
```

### Set Default Feed Rate

GET /setdefaultfeed?rate=[value]

#### Parameters:

- rate: Default feed rate in mm/min (required)

### Example:

```
curl "http://192.168.1.100/setdefaultfeed?rate=200"
```