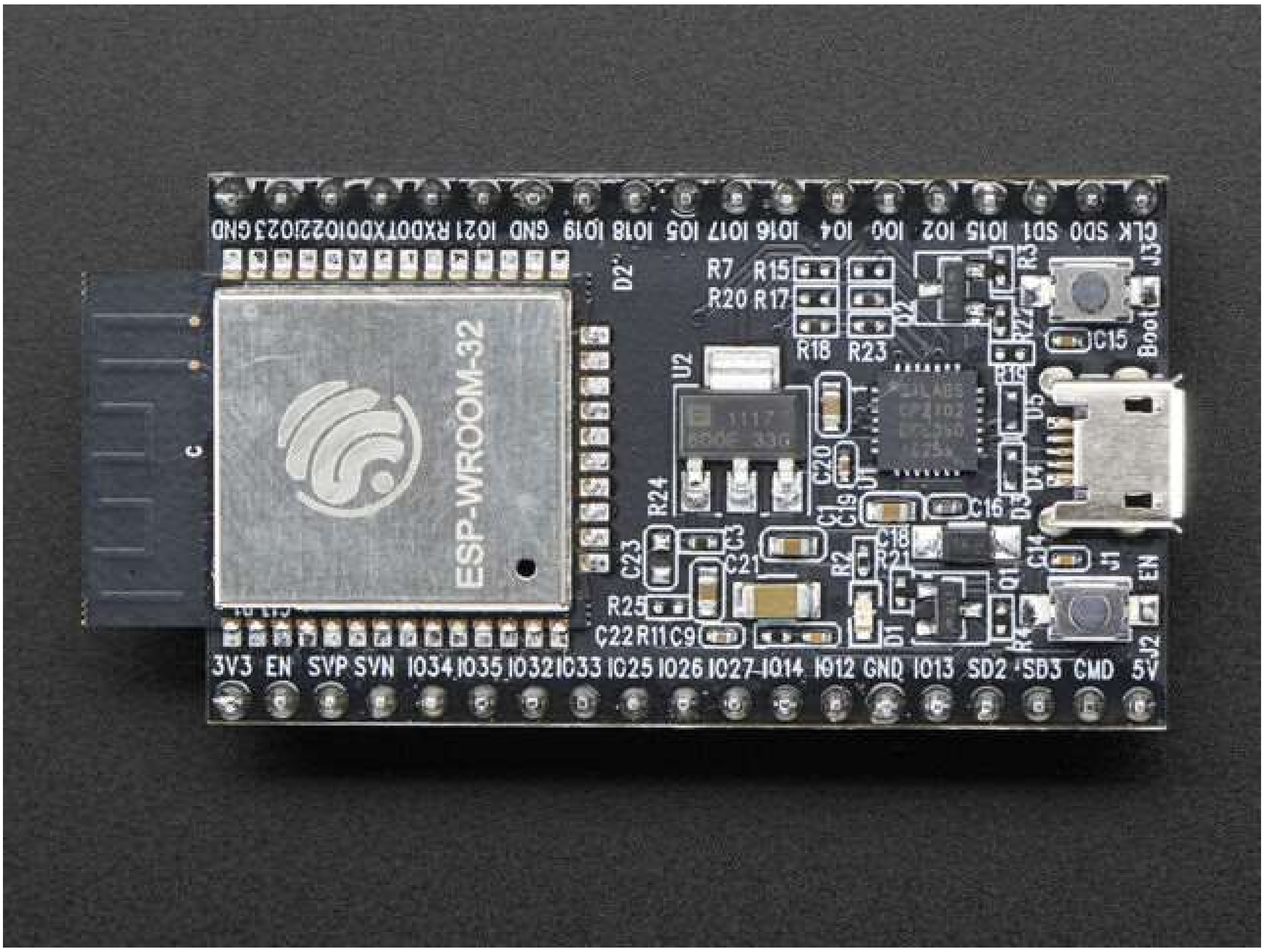
Quick reference for the ESP32



The Espressif ESP32 Development Board (image attribution: Adafruit).

Below is a quick reference for ESP32-based boards. If it is your first time working with this board it may be useful to get an overview of the microcontroller:

- General information about the ESP32 port
- MicroPython tutorial for ESP32

Installing MicroPython

See the corresponding section of tutorial: Getting started with MicroPython on the ESP32. It also includes a troubleshooting subsection.

General board control

The MicroPython REPL is on UART0 (GPIO1=TX, GPIO3=RX) at baudrate 115200. Tab-completion is useful to find out what methods an object has. Paste mode (ctrl-E) is useful to paste a large slab of Python code into the REPL.

The `machine` module:

```
import machine

machine.freq()          # get the current frequency of the CPU
machine.freq(240000000) # set the CPU frequency to 240 MHz
```

The `esp` module:

```
import esp

esp.osdebug(None)       # turn off vendor O/S debugging messages
esp.osdebug(0)          # redirect vendor O/S debugging messages to UART(0)

# low level methods to interact with flash storage
esp.flash_size()
esp.flash_user_start()
esp.flash_erase(sector_no)
esp.flash_write(byte_offset, buffer)
esp.flash_read(byte_offset, buffer)
```

The `esp32` module:

```
import esp32

esp32.hall_sensor()     # read the internal hall sensor
esp32.raw_temperature() # read the internal temperature of the MCU, in Fahrenheit
esp32.ULP()             # access to the Ultra-Low-Power Co-processor
```

Note that the temperature sensor in the ESP32 will typically read higher than ambient due to the IC getting warm while it runs. This effect can be minimised by reading the temperature sensor immediately after waking up from sleep.

Networking

The `network` module:

```python
import network

wlan = network.WLAN(network.STA_IF) # create station interface
wlan.active(True)       # activate the interface
wlan.scan()             # scan for access points
wlan.isconnected()      # check if the station is connected to an AP
wlan.connect('essid', 'password') # connect to an AP
wlan.config('mac')      # get the interface's MAC address
wlan.ifconfig()         # get the interface's IP/netmask/gw/DNS addresses

ap = network.WLAN(network.AP_IF) # create access-point interface
ap.config(essid='ESP-AP') # set the ESSID of the access point
ap.config(max_clients=10) # set how many clients can connect to the network
ap.active(True)         # activate the interface
```

A useful function for connecting to your local WiFi network is:

```python
def do_connect():
    import network
    wlan = network.WLAN(network.STA_IF)
    wlan.active(True)
    if not wlan.isconnected():
        print('connecting to network...')
        wlan.connect('essid', 'password')
        while not wlan.isconnected():
            pass
    print('network config:', wlan.ifconfig())
```

Once the network is established the `socket` module can be used to create and use TCP/UDP sockets as usual, and the `urequests` module for convenient HTTP requests.

After a call to `wlan.connect()`, the device will by default retry to connect **forever**, even when the authentication failed or no AP is in range. `wlan.status()` will return `network.STAT_CONNECTING` in this state until a connection succeeds or the interface gets disabled. This can be changed by calling `wlan.config(reconnects=n)`, where n are the number of desired reconnect attempts (0 means it won't retry, -1 will restore the default behaviour of trying to reconnect forever).

Delay and timing

Use the `time` module:

```python
import time

time.sleep(1)           # sleep for 1 second
time.sleep_ms(500)      # sleep for 500 milliseconds
time.sleep_us(10)       # sleep for 10 microseconds
start = time.ticks_ms() # get millisecond counter
delta = time.ticks_diff(time.ticks_ms(), start) # compute time difference
```

Timers

The ESP32 port has four hardware timers. Use the machine.Timer class with a timer ID from 0 to 3 (inclusive):

```
from machine import Timer

tim0 = Timer(0)
tim0.init(period=5000, mode=Timer.ONE_SHOT, callback=lambda t:print(0))

tim1 = Timer(1)
tim1.init(period=2000, mode=Timer.PERIODIC, callback=lambda t:print(1))
```

The period is in milliseconds.

Virtual timers are not currently supported on this port.

Pins and GPIO

Use the machine.Pin class:

```
from machine import Pin

p0 = Pin(0, Pin.OUT)    # create output pin on GPIO0
p0.on()                 # set pin to "on" (high) level
p0.off()                # set pin to "off" (low) level
p0.value(1)             # set pin to on/high

p2 = Pin(2, Pin.IN)     # create input pin on GPIO2
print(p2.value())       # get value, 0 or 1

p4 = Pin(4, Pin.IN, Pin.PULL_UP) # enable internal pull-up resistor
p5 = Pin(5, Pin.OUT, value=1) # set pin high on creation
```

Available Pins are from the following ranges (inclusive): 0-19, 21-23, 25-27, 32-39. These correspond to the actual GPIO pin numbers of ESP32 chip. Note that many end-user boards use their own adhoc pin numbering (marked e.g. D0, D1, ...). For mapping between board logical pins and physical chip pins consult your board documentation.

Notes:

- Pins 1 and 3 are REPL UART TX and RX respectively
- Pins 6, 7, 8, 11, 16, and 17 are used for connecting the embedded flash, and are not recommended for other uses

- Pins 34-39 are input only, and also do not have internal pull-up resistors
- The pull value of some pins can be set to `Pin.PULL_HOLD` to reduce power consumption during deepsleep.

There's a higher-level abstraction machine.Signal which can be used to invert a pin. Useful for illuminating active-low LEDs using `on()` or `value(1)`.

UART (serial bus)

See machine.UART.

```
from machine import UART

uart1 = UART(1, baudrate=9600, tx=33, rx=32)
uart1.write('hello')  # write 5 bytes
uart1.read(5)         # read up to 5 bytes
```

The ESP32 has three hardware UARTs: UART0, UART1 and UART2. They each have default GPIO assigned to them, however depending on your ESP32 variant and board, these pins may conflict with embedded flash, onboard PSRAM or peripherals.

Any GPIO can be used for hardware UARTs using the GPIO matrix, so to avoid conflicts simply provide `tx` and `rx` pins when constructing. The default pins listed below.

	UART0	UART1	UART2
tx	1	10	17
rx	3	9	16

PWM (pulse width modulation)

PWM can be enabled on all output-enabled pins. The base frequency can range from 1Hz to 40MHz but there is a tradeoff; as the base frequency *increases* the duty resolution *decreases*. See LED Control for more details.

Use the machine.PWM class:

```python
from machine import Pin, PWM

pwm0 = PWM(Pin(0))         # create PWM object from a pin
freq = pwm0.freq()         # get current frequency (default 5kHz)
pwm0.freq(1000)            # set PWM frequency from 1Hz to 40MHz

duty = pwm0.duty()         # get current duty cycle, range 0-1023 (default 512, 50%)
pwm0.duty(256)             # set duty cycle from 0 to 1023 as a ratio duty/1023, (now 25%)

duty_u16 = pwm0.duty_u16() # get current duty cycle, range 0-65535
pwm0.duty_u16(2**16*3//4)  # set duty cycle from 0 to 65535 as a ratio duty_u16/65535, (now 
75%)

duty_ns = pwm0.duty_ns()   # get current pulse width in ns
pwm0.duty_ns(250_000)      # set pulse width in nanoseconds from 0 to 1_000_000_000/freq, (now 
25%)

pwm0.deinit()              # turn off PWM on the pin

pwm2 = PWM(Pin(2), freq=20000, duty=512)  # create and configure in one go
print(pwm2)                               # view PWM settings
```

ESP chips have different hardware peripherals:

Hardware specification	ESP32	ESP32-S2	ESP32-C3
Number of groups (speed modes)	2	1	1
Number of timers per group	4	4	4
Number of channels per group	8	8	6
Different PWM frequencies (groups * timers)	8	4	4
Total PWM channels (Pins, duties) (groups * channels)	16	8	6

A maximum number of PWM channels (Pins) are available on the ESP32 - 16 channels, but only 8 different PWM frequencies are available, the remaining 8 channels must have the same frequency. On the other hand, 16 independent PWM duty cycles are possible at the same frequency.

See more examples in the Pulse Width Modulation tutorial.

ADC (analog to digital conversion)

On the ESP32, ADC functionality is available on pins 32-39 (ADC block 1) and pins 0, 2, 4, 12-15 and 25-27 (ADC block 2).

Use the machine.ADC class:

```
from machine import ADC

adc = ADC(pin)        # create an ADC object acting on a pin
val = adc.read_u16()  # read a raw analog value in the range 0-65535
val = adc.read_uv()   # read an analog value in microvolts
```

ADC block 2 is also used by WiFi and so attempting to read analog values from block 2 pins when WiFi is active will raise an exception.

The internal ADC reference voltage is typically 1.1V, but varies slightly from package to package. The ADC is less linear close to the reference voltage (particularly at higher attenuations) and has a minimum measurement voltage around 100mV, voltages at or below this will read as 0. To read voltages accurately, it is recommended to use the `read_uv()` method (see below).

ESP32-specific ADC class method reference:

class **ADC**(*pin, *, atten*)

Return the ADC object for the specified pin. ESP32 does not support different timings for ADC sampling and so the `sample_ns` keyword argument is not supported.

To read voltages above the reference voltage, apply input attenuation with the `atten` keyword argument. Valid values (and approximate linear measurement ranges) are:

- `ADC.ATTN_0DB`: No attenuation (100mV - 950mV)
- `ADC.ATTN_2_5DB`: 2.5dB attenuation (100mV - 1250mV)
- `ADC.ATTN_6DB`: 6dB attenuation (150mV - 1750mV)
- `ADC.ATTN_11DB`: 11dB attenuation (150mV - 2450mV)

Warning

Note that the absolute maximum voltage rating for input pins is 3.6V. Going near to this boundary risks damage to the IC!

ADC.read_uv()

This method uses the known characteristics of the ADC and per-package eFuse values - set during manufacture - to return a calibrated input voltage (before attenuation) in microvolts. The returned value has only millivolt resolution (i.e., will always be a multiple of 1000 microvolts).

The calibration is only valid across the linear range of the ADC. In particular, an input tied to ground will read as a value above 0 microvolts. Within the linear range, however, more accurate and consistent results will be obtained than using `read_u16()` and scaling the result with a constant.

The ESP32 port also supports the machine.ADC API:

class **`ADCBlock`**(*id*, ***, *bits*)

Return the ADC block object with the given `id` (1 or 2) and initialize it to the specified resolution (9 to 12-bits depending on the ESP32 series) or the highest supported resolution if not specified.

`ADCBlock.connect`(*pin*)

`ADCBlock.connect`(*channel*)

`ADCBlock.connect`(*channel*, *pin*)

Return the `ADC` object for the specified ADC pin or channel number. Arbitrary connection of ADC channels to GPIO is not supported and so specifying a pin that is not connected to this block, or specifying a mismatched channel and pin, will raise an exception.

Legacy methods:

`ADC.read`()

This method returns the raw ADC value ranged according to the resolution of the block, e.g., 0-4095 for 12-bit resolution.

`ADC.atten`(*atten*)

Equivalent to `ADC.init(atten=atten)`.

`ADC.width`(*bits*)

Equivalent to `ADC.block().init(bits=bits)`.

For compatibility, the `ADC` object also provides constants matching the supported ADC resolutions:

- `ADC.WIDTH_9BIT` = 9
- `ADC.WIDTH_10BIT` = 10
- `ADC.WIDTH_11BIT` = 11
- `ADC.WIDTH_12BIT` = 12

Software SPI bus

Software SPI (using bit-banging) works on all pins, and is accessed via the machine.SoftSPI class:

```
from machine import Pin, SoftSPI

# construct a SoftSPI bus on the given pins
# polarity is the idle state of SCK
# phase=0 means sample on the first edge of SCK, phase=1 means the second
spi = SoftSPI(baudrate=100000, polarity=1, phase=0, sck=Pin(0), mosi=Pin(2), miso=Pin(4))

spi.init(baudrate=200000) # set the baudrate

spi.read(10)            # read 10 bytes on MISO
spi.read(10, 0xff)      # read 10 bytes while outputting 0xff on MOSI

buf = bytearray(50)     # create a buffer
spi.readinto(buf)       # read into the given buffer (reads 50 bytes in this case)
spi.readinto(buf, 0xff) # read into the given buffer and output 0xff on MOSI

spi.write(b'12345')     # write 5 bytes on MOSI

buf = bytearray(4)      # create a buffer
spi.write_readinto(b'1234', buf) # write to MOSI and read from MISO into the buffer
spi.write_readinto(buf, buf) # write buf to MOSI and read MISO back into buf
```

Warning

Currently *all* of `sck`, `mosi` and `miso` *must* be specified when initialising Software SPI.

Hardware SPI bus

There are two hardware SPI channels that allow faster transmission rates (up to 80Mhz). These may be used on any IO pins that support the required direction and are otherwise unused (see Pins and GPIO) but if they are not configured to their default pins then they need to pass through an extra layer of GPIO multiplexing, which can impact their reliability at high speeds. Hardware SPI channels are limited to 40MHz when used on pins other than the default ones listed below.

	HSPI (id=1)	VSPI (id=2)
sck	14	18
mosi	13	23
miso	12	19

Hardware SPI is accessed via the machine.SPI class and has the same methods as software SPI above:

```
from machine import Pin, SPI

hspi = SPI(1, 10000000)
hspi = SPI(1, 10000000, sck=Pin(14), mosi=Pin(13), miso=Pin(12))
vspi = SPI(2, baudrate=80000000, polarity=0, phase=0, bits=8, firstbit=0, sck=Pin(18),
mosi=Pin(23), miso=Pin(19))
```

Software I2C bus

Software I2C (using bit-banging) works on all output-capable pins, and is accessed via the machine.SoftI2C class:

```
from machine import Pin, SoftI2C

i2c = SoftI2C(scl=Pin(5), sda=Pin(4), freq=100000)

i2c.scan()              # scan for devices

i2c.readfrom(0x3a, 4)   # read 4 bytes from device with address 0x3a
i2c.writeto(0x3a, '12') # write '12' to device with address 0x3a

buf = bytearray(10)     # create a buffer with 10 bytes
i2c.writeto(0x3a, buf)  # write the given buffer to the peripheral
```

Hardware I2C bus

There are two hardware I2C peripherals with identifiers 0 and 1. Any available output-capable pins can be used for SCL and SDA but the defaults are given below.

	I2C(0)	I2C(1)
scl	18	25
sda	19	26

The driver is accessed via the machine.I2C class and has the same methods as software I2C above:

```
from machine import Pin, I2C

i2c = I2C(0)
i2c = I2C(1, scl=Pin(5), sda=Pin(4), freq=400000)
```

I2S bus

See machine.I2S.

```
from machine import I2S, Pin

i2s = I2S(0, sck=Pin(13), ws=Pin(14), sd=Pin(34), mode=I2S.TX, bits=16, format=I2S.STEREO,
rate=44100, ibuf=40000) # create I2S object
i2s.write(buf)             # write buffer of audio samples to I2S device

i2s = I2S(1, sck=Pin(33), ws=Pin(25), sd=Pin(32), mode=I2S.RX, bits=16, format=I2S.MONO,
rate=22050, ibuf=40000) # create I2S object
i2s.readinto(buf)          # fill buffer with audio samples from I2S device
```

The I2S class is currently available as a Technical Preview. During the preview period, feedback from users is encouraged. Based on this feedback, the I2S class API and implementation may be changed.

ESP32 has two I2S buses with id=0 and id=1

Real time clock (RTC)

See machine.RTC

```
from machine import RTC

rtc = RTC()
rtc.datetime((2017, 8, 23, 1, 12, 48, 0, 0)) # set a specific date and time
rtc.datetime() # get date and time
```

WDT (Watchdog timer)

See machine.WDT.

```
from machine import WDT

# enable the WDT with a timeout of 5s (1s is the minimum)
wdt = WDT(timeout=5000)
wdt.feed()
```

Deep-sleep mode

The following code can be used to sleep, wake and check the reset cause:

```
import machine

# check if the device woke from a deep sleep
if machine.reset_cause() == machine.DEEPSLEEP_RESET:
    print('woke from a deep sleep')

# put the device to sleep for 10 seconds
machine.deepsleep(10000)
```

Notes:

- Calling `deepsleep()` without an argument will put the device to sleep indefinitely
- A software reset does not change the reset cause
- There may be some leakage current flowing through enabled internal pullups. To further reduce power consumption it is possible to disable the internal pullups:

  ```
  p1 = Pin(4, Pin.IN, Pin.PULL_HOLD)
  ```

  After leaving deepsleep it may be necessary to un-hold the pin explicitly (e.g. if it is an output pin) via:

  ```
  p1 = Pin(4, Pin.OUT, None)
  ```

SD card

See machine.SDCard.

```
import machine, os

# Slot 2 uses pins sck=18, cs=5, miso=19, mosi=23
sd = machine.SDCard(slot=2)
os.mount(sd, "/sd")  # mount

os.listdir('/sd')    # list directory contents

os.umount('/sd')     # eject
```

RMT

The RMT is ESP32-specific and allows generation of accurate digital pulses with 12.5ns resolution. See esp32.RMT for details. Usage is:

```
import esp32
from machine import Pin

r = esp32.RMT(0, pin=Pin(18), clock_div=8)
r   # RMT(channel=0, pin=18, source_freq=80000000, clock_div=8)
# The channel resolution is 100ns (1/(source_freq/clock_div)).
r.write_pulses((1, 20, 2, 40), 0) # Send 0 for 100ns, 1 for 2000ns, 0 for 200ns, 1 for 4000ns
```

OneWire driver

The OneWire driver is implemented in software and works on all pins:

```
from machine import Pin
import onewire

ow = onewire.OneWire(Pin(12)) # create a OneWire bus on GPIO12
ow.scan()               # return a list of devices on the bus
ow.reset()              # reset the bus
ow.readbyte()           # read a byte
ow.writebyte(0x12)      # write a byte on the bus
ow.write('123')         # write bytes on the bus
ow.select_rom(b'12345678') # select a specific device by its ROM code
```

There is a specific driver for DS18S20 and DS18B20 devices:

```
import time, ds18x20
ds = ds18x20.DS18X20(ow)
roms = ds.scan()
ds.convert_temp()
time.sleep_ms(750)
for rom in roms:
    print(ds.read_temp(rom))
```

Be sure to put a 4.7k pull-up resistor on the data line. Note that the `convert_temp()` method must be called each time you want to sample the temperature.

NeoPixel and APA106 driver

Use the `neopixel` and `apa106` modules:

```
from machine import Pin
from neopixel import NeoPixel

pin = Pin(0, Pin.OUT)   # set GPIO0 to output to drive NeoPixels
np = NeoPixel(pin, 8)   # create NeoPixel driver on GPIO0 for 8 pixels
np[0] = (255, 255, 255) # set the first pixel to white
np.write()              # write data to all pixels
r, g, b = np[0]         # get first pixel colour
```

The APA106 driver extends NeoPixel, but internally uses a different colour order:

```
from apa106 import APA106
ap = APA106(pin, 8)
r, g, b = ap[0]
```

Warning

By default `NeoPixel` is configured to control the more popular *800kHz* units. It is possible to use alternative timing to control other (typically 400kHz) devices by passing `timing=0` when constructing the `NeoPixel` object.

For low-level driving of a NeoPixel see `machine.bitstream`. This low-level driver uses an RMT channel by default. To configure this see `RMT.bitstream_channel`.

APA102 (DotStar) uses a different driver as it has an additional clock pin.

Capacitive touch

Use the `TouchPad` class in the `machine` module:

```
from machine import TouchPad, Pin

t = TouchPad(Pin(14))
t.read()              # Returns a smaller number when touched
```

`TouchPad.read` returns a value relative to the capacitive variation. Small numbers (typically in the *tens*) are common when a pin is touched, larger numbers (above *one thousand*) when no touch is present. However the values are *relative* and can vary depending on the board and surrounding composition so some calibration may be required.

There are ten capacitive touch-enabled pins that can be used on the ESP32: 0, 2, 4, 12, 13 14, 15, 27, 32, 33. Trying to assign to any other pins will result in a `ValueError`.

Note that TouchPads can be used to wake an ESP32 from sleep:

```
import machine
from machine import TouchPad, Pin
import esp32

t = TouchPad(Pin(14))
t.config(500)               # configure the threshold at which the pin is considered touched
esp32.wake_on_touch(True)
machine.lightsleep()        # put the MCU to sleep until a touchpad is touched
```

For more details on touchpads refer to Espressif Touch Sensor.

DHT driver

The DHT driver is implemented in software and works on all pins:

```
import dht
import machine

d = dht.DHT11(machine.Pin(4))
d.measure()
d.temperature() # eg. 23 (°C)
d.humidity()    # eg. 41 (% RH)

d = dht.DHT22(machine.Pin(4))
d.measure()
d.temperature() # eg. 23.6 (°C)
d.humidity()    # eg. 41.3 (% RH)
```

WebREPL (web browser interactive prompt)

WebREPL (REPL over WebSockets, accessible via a web browser) is an experimental feature available in ESP32 port. Download web client from https://github.com/micropython/webrepl (hosted version available at http://micropython.org/webrepl), and configure it by executing:

```
import webrepl_setup
```

and following on-screen instructions. After reboot, it will be available for connection. If you disabled automatic start-up on boot, you may run configured daemon on demand using:

```python
import webrepl
webrepl.start()

# or, start with a specific password
webrepl.start(password='mypass')
```

The WebREPL daemon listens on all active interfaces, which can be STA or AP. This allows you to connect to the ESP32 via a router (the STA interface) or directly when connected to its access point.

In addition to terminal/command prompt access, WebREPL also has provision for file transfer (both upload and download). The web client has buttons for the corresponding functions, or you can use the command-line client `webrepl_cli.py` from the repository above.

See the MicroPython forum for other community-supported alternatives to transfer files to an ESP32 board.