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Programmable Power Unit Supplies Based on Quick Charge Technology

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Abstract

The work presents the development and investigation of a programmable power block with remote control based on Quick Charge technology. It was figured out that power sources/chargers for mobile phones with Quick Charge 2.0, 3.0 technology can be used to construct a programmable power block with remote control. For this purpose, an additional control module needs to be developed. In this case, the output voltage level can be programmatically set through the high-voltage dedicated Qualcomm charging port (HVDCP). The remotely set output voltage is extracted from the HVDCP port lines: Vbus, Gnd (pins 1, 4). The control of the output voltage is achieved through voltage levels of specific duration using the D+, D- lines of the HVDCP port.

The developed scheme of the programmable power source based on Quick Charge technology requires specialized software. The control module program should provide identification of power adapters that support Quick Charge 2.0, 3.0 technology. In this case, the HVDCP continuous mode allows remote control of the output voltage from 3.6V to 20V when using the control module with corresponding software.

The article presents the scheme and software for the control module of the programmable power block based on Quick Charge technology, which operate in accordance with the developed algorithms. Modeling and experimental research confirmed the possibility of remote change of the adapter's output voltage using the proposed control module and corresponding software.

Thanks to the online processing and monitoring of obtained data on a personal computer, both manual and automatic control of the output voltage level are possible. Remote control of the programmable power block can be done through the USB port or wireless interfaces like Bluetooth, Wi-Fi. For this purpose, the microcontroller of the control module must support a UART interface to which shields, modules, or interface converters can be connected to interact with remote control elements.

Keywords

Programmable power unit; Quick Charge; control module; HVDCP

1. Introduction

Power sources provide electrical energy in the form of operating voltage to a wide spectrum of systems. With the increasing use of IoT devices in industrial equipment, home automation, and

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medicine, there is a growing need for optimizing power control elements. In many applications, programmable power sources can significantly enhance system capabilities and efficiency. While traditional power sources have fixed output voltage values, programmable power sources offer greater flexibility and multiple operational modes. Such programmable power sources with software controllers provide control over various voltage, current, power, and operating mode settings [1].

In certain chemical processes, the power source must deliver a predetermined power level, often referred to as Constant Power (CP). This requires constant monitoring of the process and a programmable power source that interacts with the control system in real-time mode. Programming is done by the controller, and the power block responds to these commands. Such a power source may even have a built-in controller, where the user simply writes and runs a program that suits his process. As a result, a standard programmable power source can meet specific and diverse user requirements [2].

Programmable power sources are utilized in various applications, including galvanic processes in industries, automated test equipment, testing, certification, and calibration processes, troubleshooting and modeling, medical diagnostic and treatment systems, hydrogen and helium generation systems, testing of research and development equipment [1-10].

One significant requirement for modern switched-mode power supplies is the ability to remotely control output parameters, achieved through remote control units or computers [3]. Software control offers several advantages, including the ability to create custom power supply operation modes.

The main applications of programmable power sources are [2]:

- Operating the devices with unknown or variable voltages.
- Working with devices that have unique power supply requirements not covered by standard power supplies.
- Dynamically adjusting voltage during operation.
- Switching between operational modes for different devices.

Programmable power sources can fulfill these requirements, allowing easy switching between different operation modes. For example, an intelligent charger with a programmable power source can charge a battery by initially supplying constant current (CC) and then switching to constant voltage (CV) mode as the battery approaches full charge. If the power source exceeds the user-set current limit in CV mode, it can automatically revert to CC mode [2].

The objective of this work is to study power blocks (chargers) with Quick Charge technology and develop a programmable power block based on them, capable of remote (software) voltage control via USB port or Wi-Fi wireless network.

To achieve this objective, the following tasks need to be addressed:

1. Study the characteristics of output voltage variation through the high-voltage dedicated Qualcomm charging port (HVDCP) in Quick Charge technology.
2. Develop an algorithm for detecting HVDCP on devices that support fast charging functionality.
3. Design a device that interfaces through HVDCP and allows setting the output voltage of the power block.
4. Develop software that enables software-based adjustment of the power block's output voltage through the USB port.
5. Investigate the Quick Charge-based programmable power block using the developed software.

2. Researching the Characteristics of Output Voltage Variation Through the Qualcomm High-Voltage Dedicated Charging Port (HVDCP).

In response to growing demand, the capabilities of USB technology are constantly evolving. The power of USB 2.0 power sources, originally 2.5 watts (5V at 0.5A), has been increased to 4.5 watts (5V at 0.9A) with the introduction of USB 3.0. Similarly, the power of power sources supporting USB BC 1.2 has also increased to 7.5 watts (5V at 1.5A). However, the true breakthrough in power source capabilities came with the advent of Qualcomm's Quick Charge (QC) technology. The Quick Charge 2.0 and 3.0 specifications developed by Qualcomm incorporate a comprehensive power delivery mechanism, significantly enhancing power source capabilities up to 60 watts (20V at 3A) [11, 12].

Qualcomm Quick Charge is employed in smartphones, chargers, external power banks, and car sockets. The QC technology from Qualcomm, specifically versions 2.0 and 3.0, has gained popularity due to its support and widespread availability in the majority of modern smartphones. Other manufacturers also employ similar quick charging technologies in their products (**Ошибка! Источник ссылки не найден.**).

Table 1
Charging Standards

Standard	Maximum Value		
	Voltage	Amperage	Power
USB 1.0	5 V	0,5 A	2,5 W
USB 2.0	5 V	0,5 A	2,5 W
USB 3.0	5 V	0,9 A	4,5 W
USB PD	20 V	5 A	100 W
Qualcomm Quick Charge 1.0	5 V	2 A	10 W
Qualcomm Quick Charge 2.0	12 V	2 A	18 W
Qualcomm Quick Charge 3.0	20 V	4,6 A	18 W
Qualcomm Quick Charge 4.0+	20 V	4,6 A	27 W
Samsung Adaptive Fast Charging	9 V	2 A	18 W
Apple Fast Charging	14,5 V	2 A	29 W
Huawei Super Charge	5 V	5 A	25 W
Huawei Super Charge 2.0	10 V	4 A	40 W
Motorola Turbo Power	12 V	5,7 A	28,5 W
OPPO VOOC	5 V	5 A	25 W
OPPO Super VOOC	5 V	10 A	50 W
OnePlus Dash Charge	5 V	4 A	20 W
OnePlus Warp Charge	5 V	6 A	30 W
MediaTek Pump Express 2.0+	20 V	4,5 A	15 W
MediaTek Pump Express 3.0	6 V	5 A	30 W
MediaTek Pump Express 4.0	6 V	5 A	25 W

A power adapter for a mobile phone is cheaper than a comparable power block. It is practical to use a mobile phone power adapter/charger as the basis for constructing a programmable power block with remote control. The interaction between the power adapter with Quick Charge support and the mobile phone is illustrated in Figure 1.

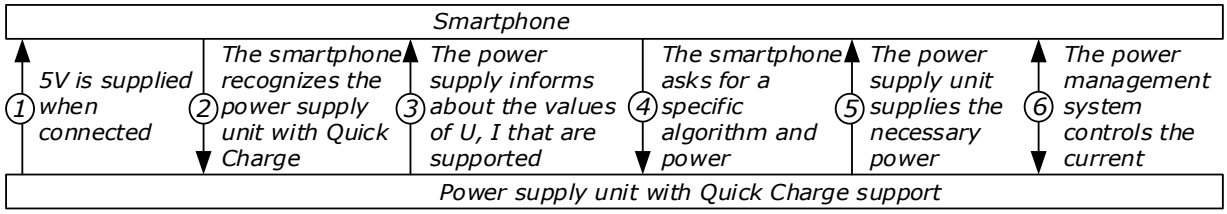

Figure 1: Interaction Algorithm between Quick Charge-Compatible Power Adapter and Smartphone

The Qualcomm High Voltage Dedicated Charging Port (HVDCP) is used for interacting with the load via D+/D lines and setting the voltage level for the power source at 5V, 9V, 12V, and 20V or voltage adjustment steps for QC 3.0 [12].

Interactions between QC2.0+ devices and the adapter occur through the D+ and D- USB lines. The QC protocol does not adhere to USB characteristics and utilizes specialized logical levels. To control the adapter, it is necessary to generate 0V, 0.6V, and 3.3V levels.

How to determine which type of adapter is connected? In QC1.0, compatible adapters have a distinctive feature: the D+ and D- lines inside the adapter are shorted (Figure 2, a).

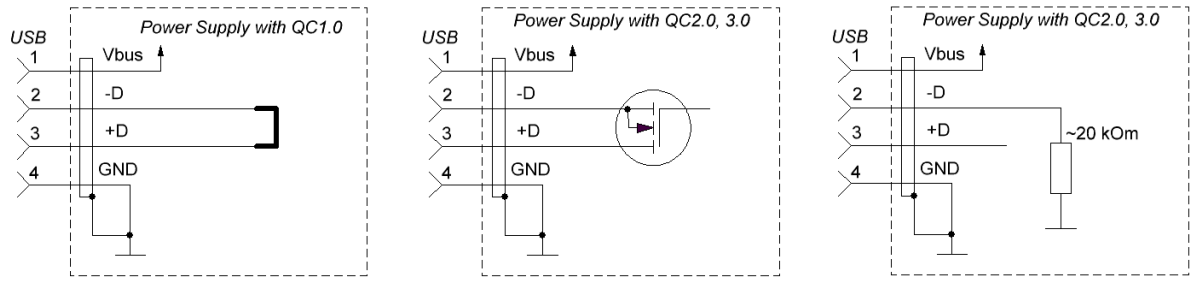

Figure 2: Operation Features: a) Power Supply with QC1.0; b) Power Supply with QC2.0, 3.0; c) Power Supply with QC2.0, 3.0 disconnects the lines and adds a 20kΩ pull-down resistor to the D- line.

QC2.0 adapters, after being powered on, output a voltage of 5V, and the D+ and D- lines inside are still shorted by a transistor (Figure 2, b), ensuring compatibility with QC1.0. By applying a voltage of 0.6V to the D+ line and waiting for approximately 1.5 seconds, the adapter will open the lines and connect a 20kΩ pull-down resistor to the D- line (Figure 2, c)

If D- is pulled down to 0 for a few milliseconds, the adapter will switch to the HVDCP special mode. Setting specific combinations of logic levels on the lines allows obtaining the required voltage (Table 2). Each adapter is protected against interference, so the indicated levels should remain unchanged for 60ms for the changes to take effect [11-13].

Table 2

Output Voltage Settings in QC2.0, QC 3.0 Adapters

D+	D-	Output
3.3V	3.3V	20V
0.6V	0.6V	12V
3.3V	0.6V	9V
0.6V	Gnd	5V (default)
0.6V	3.3V	3,6V-20V (continuous mode)

It is not possible to programmatically differentiate QC2.0 from QC3.0. QC3.0 inherits everything from QC2.0; however, it allows setting any voltage at the output. This is achieved using the Continuous Mode. The timing diagram for generating the output voltage of a power adapter with QC2.0, 3.0 is provided in Figure 3 [13, 14].

Therefore, depending on the control signals on the D+ and D- lines, it is possible to programmatically set the desired output voltage of the power source. This enables dynamic adjustment of operating modes and remote control of energy consumption levels for various devices. To achieve this, it is necessary to develop a control module and corresponding software for its operation.

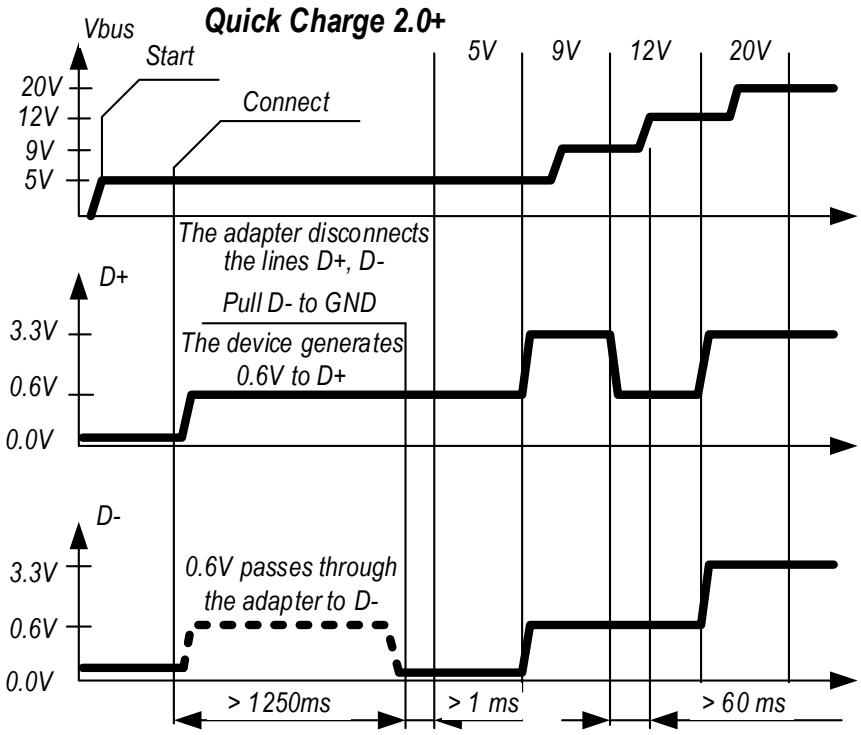

Figure 3: Timing Diagram for Generating Output Voltage of Power Adapter with QC2.0, 3.0

3. Development of a Programmable Power Supply Unit based on Quick Charge Technology

Development of a Programmable Power Supply Unit based on Quick Charge Technology begins with designing its structure and operational algorithm.

The structural diagram of a programmable power supply unit with remote control based on Quick Charge technology is illustrated in Figure 4.

The diagram comprises:

- A power source (charging device) built upon Quick Charge technology.
- A control module with the ability to connect through a USB port or wireless Wi-Fi network to a control device, enabling remote management of operating modes.
- A control device (computer, laptop, smartphone, or specialized control remote).

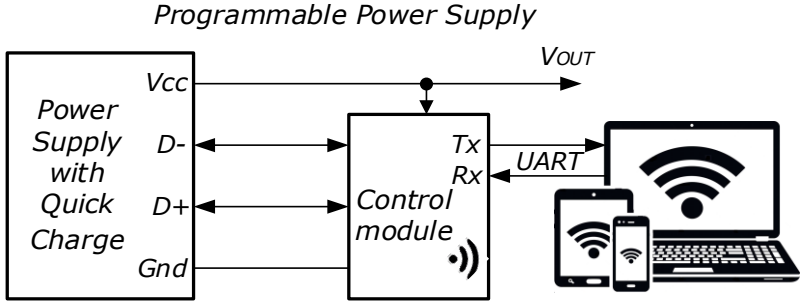

Figure 4: Structural Diagram of Power Supply Unit with Remote Control based on Quick Charge Technology

3.1. Development of HVDCP Detection Algorithm for the Programmable Power Supply Based on Quick Charge Technology.

For the interaction between the control module and the power supply unit built on the basis of Quick Charge technology, an algorithm has been developed. The initial operation algorithm of the control module (Figure 4) of the programmable power supply unit involves interaction with the power adapter and determining whether it supports the QC2.0, 3.0 protocol [11-13]:

1. The control module connects to the power adapter through HVDCP and detects that the VBUS voltage exceeds the voltage range of 0.8-4V. This indicates that the control module is connected to the power adapter.

2. The HVDCP of the power adapter closes D+ / D- through a transistor (Figure 3, b); the control module applies a voltage of 0.6V to D+, and the power adapter compares the voltage on D- with a threshold value of 0.25-0.4V. If the voltage on D- is higher, it means that HVDCP supports the QC2.0 protocol. If the voltage on D+ exceeds 0.25-0.4V during a period of time (1-1.5s), the control module confirms the completion of the QC2.0, 3.0 detection procedure.

3. The HVDCP of the power adapter disconnects D+/D- and activates the Pull Down 20kΩ resistor to the D- line to inform the control module that HVDCP supports QC. After the voltage on D- drops below 0.25V within 1ms, HVDCP can start responding to the voltage request sent by the control module (Table 2).

3.2. Development of Control Module for the Programmable Power Supply with Remote Control Based on Quick Charge Technology.

Figure 5 illustrates the control module scheme for the programmable power supply unit with remote control based on Quick Charge technology. The core of the control module is the Arduino Nano (microcontroller ATmega328P) (DD1). Resistors R1, R2, and R3, R4 create a voltage divider. Applying logic levels 1 and 0 to DP_H (DM_H) and DP_L (DM_L) lines respectively results in a voltage of 0.6V; logic levels 0 and 0 lead to 0V; logic levels 1 and 1 yield a voltage of 3.6V. Zener diodes VD1 and VD2 limit the voltage level to 3.6V when supplied with 5V [14].

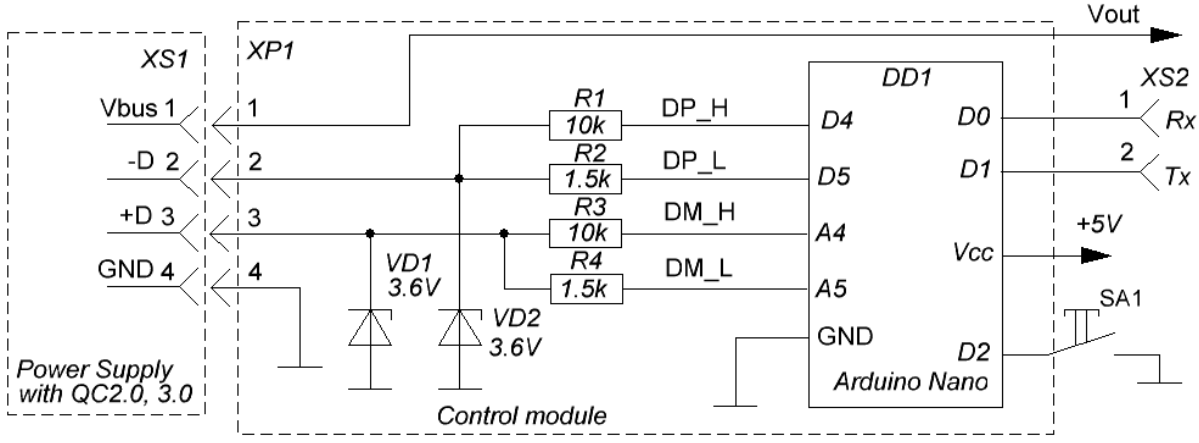

Figure 5: Control Module Schematic with Arduino Nano (ATmega328P Microcontroller)

The output voltage (Vout) of the programmable power supply unit with remote control based on Quick Charge technology is extracted from the 1st pin (Vbus) XS1. The output voltage (Vout) can have fixed values of +5V, +9V, +12V, and +20V. The selection of the output voltage is accomplished using button SA1. By default, the output voltage is set to +5V. With each pressing of button SA1, the output voltage will change accordingly to Table 2. If the power adapter supports QC3.0 and higher technologies, it can be switched to Continuous Mode, and the output voltage can be programmatically set from 3.6V to 20V in 200mV increments through the UART interface (Rx, Tx). If the power adapter

supports QC2.0, then fixed values of +5V, +9V, +12V, and +20V can be programmatically set through the UART interface. For power adapters supporting QC1.0, it is not possible to programmatically set the output voltage through the UART interface.

3.3. Software Development for Control Module to Change Output Voltage Using the Tactile Button of the Programmable Power Supply.

To ensure the functionality of the control module for the programmable power supply unit in accordance with the developed algorithm, it is necessary to create the appropriate software (QC_SWITCH program). The QC_SWITCH program is written in the Arduino IDE environment and enables the adjustment of the output voltage through the press of the SA1 button (Figure 5).

Here is the program listing for QC_SWITCH:

```
#define DP_H 4
#define DP_L 5
#define DM_H A4
#define DM_L A5

byte mode = 0;
void DP_0V();
void DP_06V();
void DP_33V();
void DM_0V();
void DM_06V();
void DM_33V();

void setup() {
  pinMode (2, INPUT_PULLUP);
      attachInterrupt(0,    blink,
FALLING);
  pinMode(DP_H, OUTPUT);
  pinMode(DP_L, OUTPUT);
  DP_06V();
  delay(1500);

  pinMode(DM_H, OUTPUT);
  pinMode(DM_L, OUTPUT);
  DM_0V();
  delay(3);
}

void loop() {
  switch (mode) {
    case 0://5V
      DP_06V();
      DM_0V();
      break;
    case 1://9V
      DP_33V();
      DM_06V();
      break;
    case 2://12V
      DP_06V();
      DM_06V();
      break;

    case 3://20V
      DP_33V();
      DM_33V();
      break;
  }
}

void blink(){
  mode++;
  if (mode > 3)mode = 0;
}

void DP_0V (){
  digitalWrite(DP_H, LOW);
  digitalWrite(DP_L, LOW);
}

void DP_06V (){
  digitalWrite(DP_H, HIGH);
  digitalWrite(DP_L, LOW);
}

void DP_33V(){
  digitalWrite(DP_H, HIGH);
  digitalWrite(DP_L, HIGH);
}

void DM_0V(){
  digitalWrite(DM_H, LOW);
  digitalWrite(DM_L, LOW);
}

void DM_06V(){
  digitalWrite(DM_H, HIGH);
  digitalWrite(DM_L, LOW);
}

void DM_33V(){
  digitalWrite(DM_H, HIGH);
  digitalWrite(DM_L, HIGH);
}
```

In lines 14-27 of the QC_SWITCH program, the operating modes of the microcontroller ports are configured, the interrupt mode INT0 is set up for pressing the SA1 button, an output voltage of 0.6V is set on the D+ line, and a delay of 1.5 seconds is introduced to allow the control module to confirm the completion of the QC2.0, 3.0 detection procedure. A voltage of 0V is set on the D- line for 3 ms to prompt the power adapter through HVDCP to start responding to voltage requests from the control module.

In lines 29-49, the state of the variable "mode" is analyzed, which can take values from 0 to 3. The value of "mode" changes in the "blink" function (lines 51-54) when the SA1 button is pressed. The value of "mode" determines the output voltage of the power adapter through HVDCP (Vout in Figure 5). Lines 56-84 contain functions to generate voltages of 0V, 0.6V, and 3.3V on the D+ and D- lines.

3.4. Investigation of the Programmable Power Supply Control Module.

To verify the voltage values on the D+ and D- lines of the charger, we will conduct a study of the control module in the virtual environment of Proteus and on a prototype board.

3.4.1. Computer Simulation of the Control Module in Proteus Environment.

The schematic diagram for modeling the operation of the control module in the Proteus environment is shown in Figure 6.

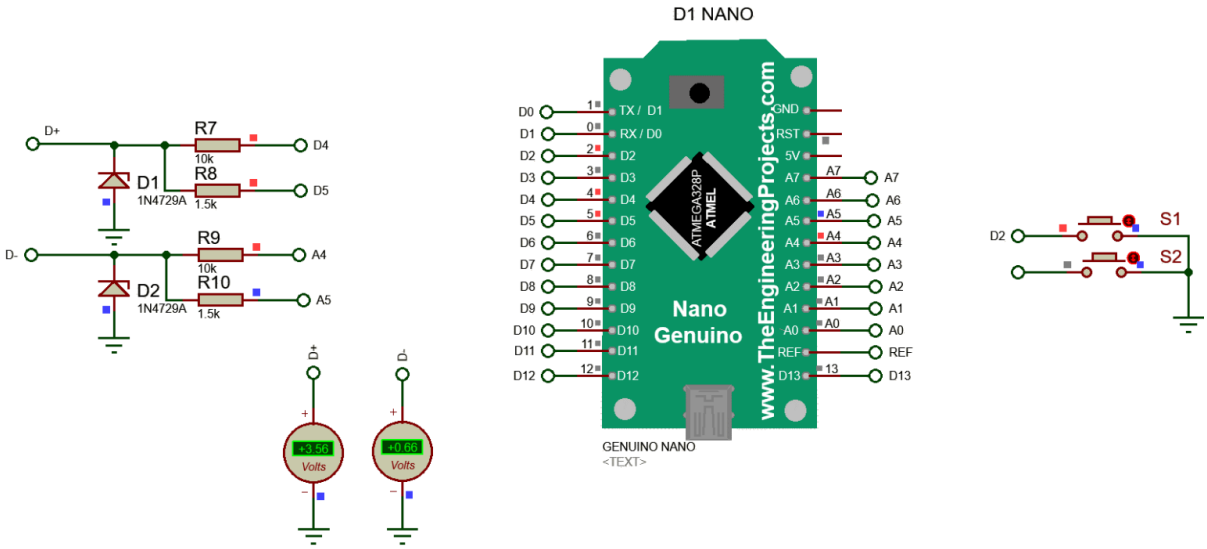

Figure 6: Modeling the Operation of the Control Module in the Proteus Environment

The QC_SWITCH program was compiled into a binary file and uploaded to the Arduino Nano module (Figure 6). During computer simulation in the Proteus environment, pressing the SA1 button resulted in voltage changes on the D+/D- lines: 0.66V/0V, 3.56V/0.66V, 0.66V/0.66V, 3.56V/3.56V. Thus, the circuit and software operate correctly, and further experiments can be conducted.

3.4.2. Investigation of the Control Module on a Prototype Board

The control module schematic was implemented on a prototype board (Figure 7). The Arduino Nano module was programmed with the QC_SWITCH program using the Arduino IDE. The Xiaomi MOY-11-EZ charger was used as the power adapter. Figure 7 shows experimental investigation of the interaction between the control module and the power adapter to implement the programmable power supply based on Quick Charge technology.

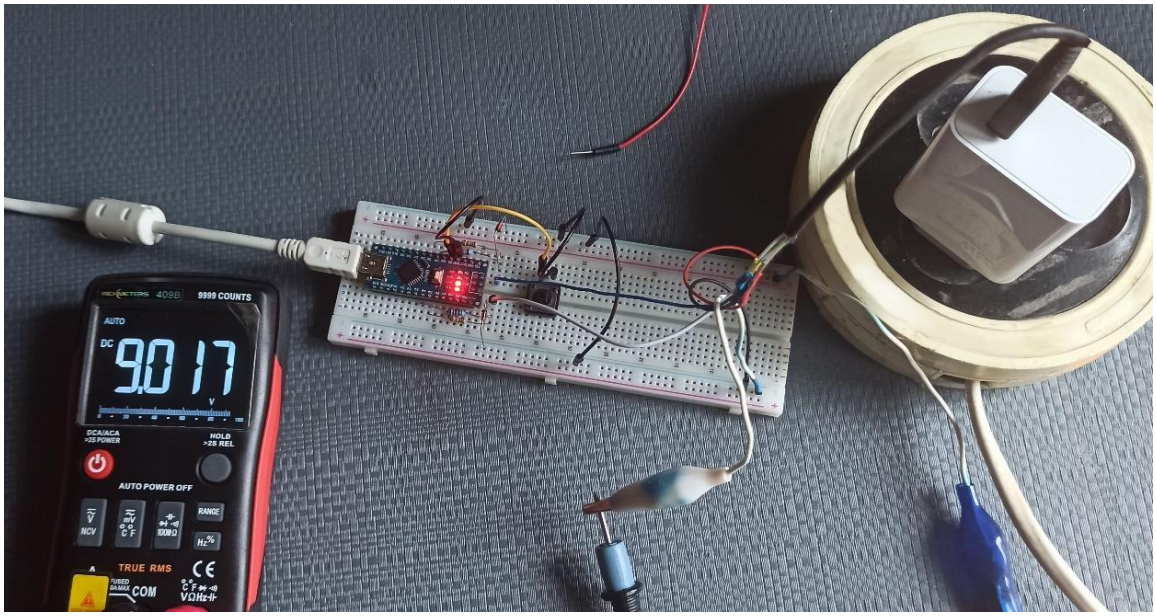

Figure 7: Experimental Investigation of the Implementation of the Programmable Power Supply based on Quick Charge Technology

As a result of the studies, the circuit operated according to the specified algorithm, and output voltage values of 5.185V, 9.017V, 12.02V, and 18.98V were obtained. It was found that the Forever Core QC3.0 FC-01 22.5W Power Bank and the RavPower PP-PC132 power adapter also worked with the control module. Other power adapters (InFinix XC02, USlion USR UD7656, Remax PD P-96 Power Bank, Xiaomi Mi Power Bank 2) only provided a voltage of +5V at the output and did not change the output voltage upon pressing SA1, despite being labeled as QC3.0. Therefore, changes need to be made to the control module program for further investigation, which should include the detection of the QC protocol supported by the power adapter. In the case of QC2.0 and QC3.0, an attempt should be made to switch to Continuous Mode and remotely control the output voltage Vout.

3.5. Development of Algorithm for Software Control and Interrogation of the Power Adapter

The algorithm for software control and polling of the QC1.0, QC2.0, and QC3.0 power adapters to generate the required output voltage on HVDCP [11-14] is shown in Figure 8.

The QC technology supported by the power adapter can be determined basing on the voltage level on D-. To do this, the control module applies a voltage of 0.6V to the D+ line. If after 1.5 seconds the voltage on the D- line equals 0.6V, it means that the adapter supports only QC1.0. If the voltage on the D- line is 0V, the adapter supports QC2.0. The adapter will enter HVDCP discrete mode. Setting one of the combinations of logic levels on the D+ and D- lines within 60ms allows obtaining the required voltage (Table 2). The QC3.0 power adapter can be switched to HVDCP Continuous mode [14]. Transition to Continuous mode does not change the current voltage (you can start with 9V, switch to Continuous mode, and then change to 11V, or start in Continuous mode directly from 5V). Exiting Continuous mode is possible only in the 5V state. From the 5V, 9V, 12V, 20V modes, you can perform transition to any other mode. Control of the output voltage in Continuous mode is done discretely using pulses on D+ or D-. Each pulse has a duration of about 1 ms (Figure 9).

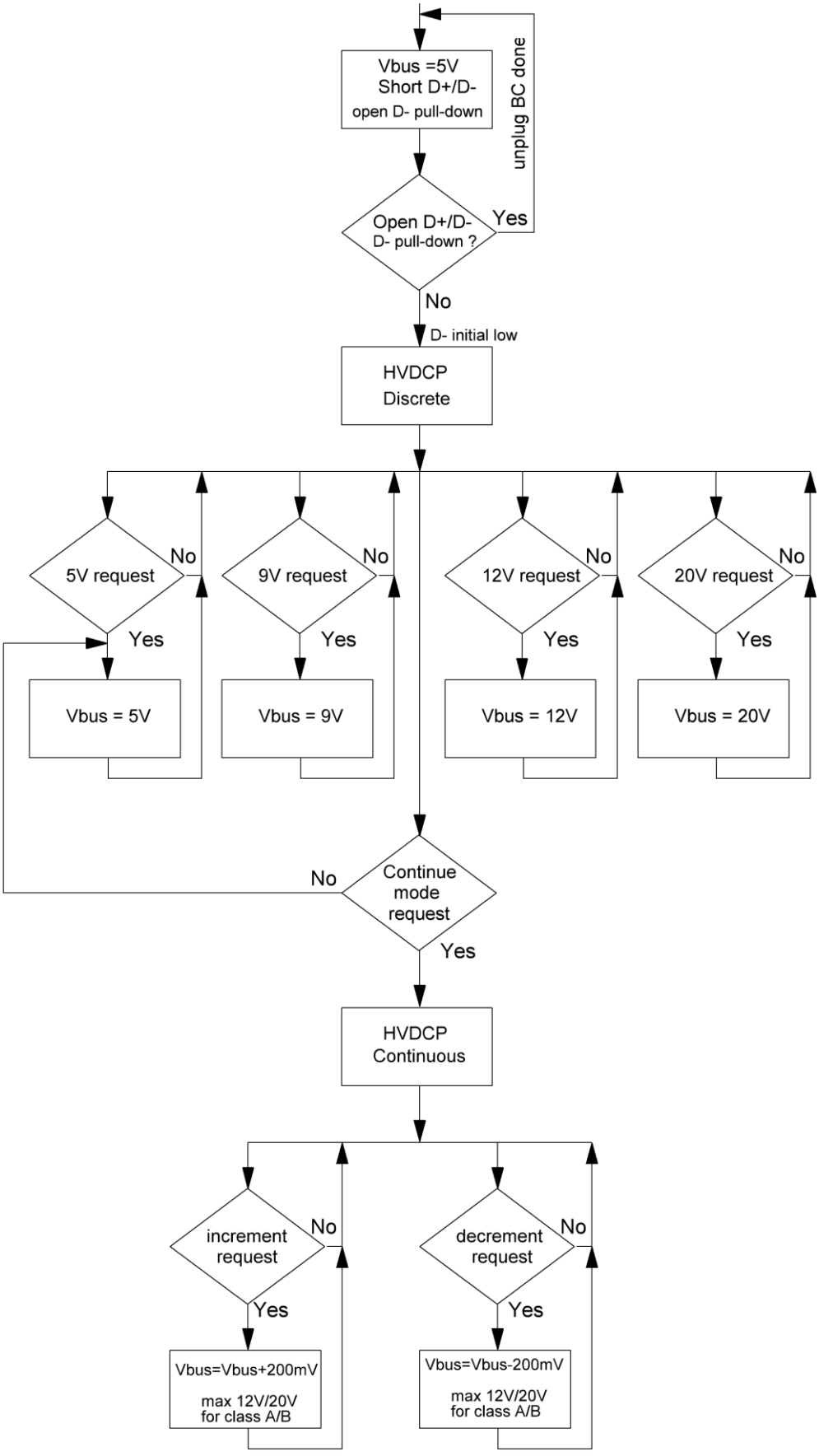

Figure 8: Algorithm for Software Control and Polling of the Power Adapter

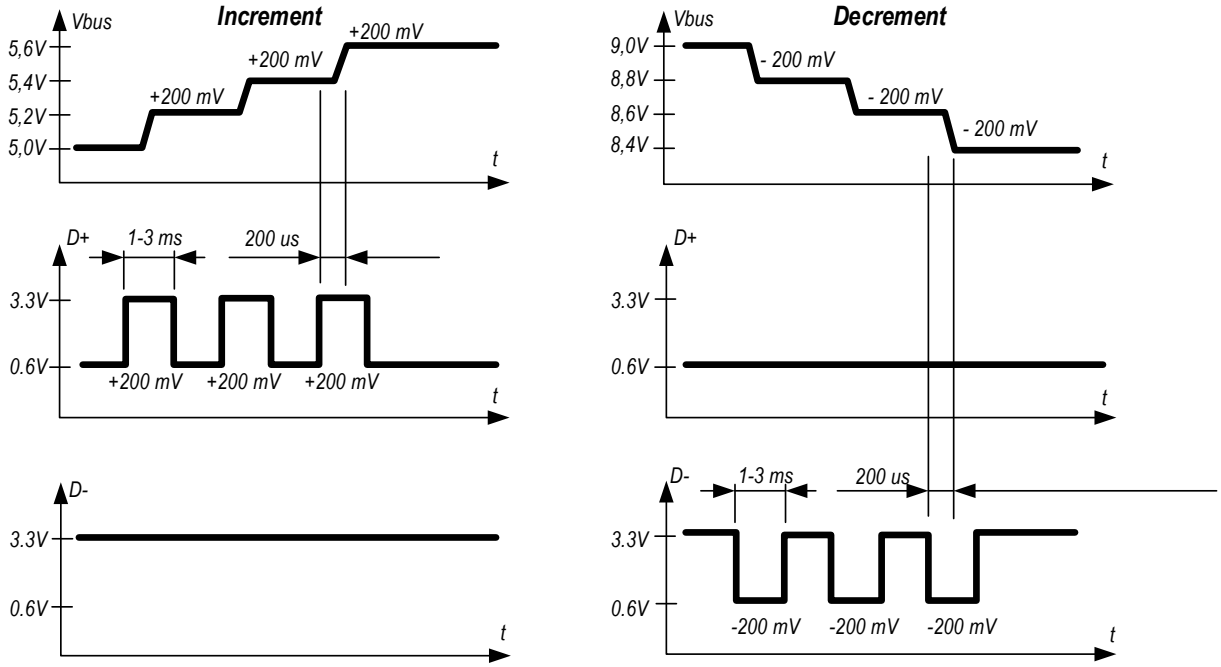

Figure 9: Control of the Output Voltage of the Power Adapter in HVDCP Continuous Mode

3.6. Development of Software for Controlling the Operation of the Programmable Power Supply via USB Port of a Personal Computer

The next step in implementing the programmable power supply with remote control based on Quick Charge technology was the development of the QuickCharge.h library and the QC_Remote program for controlling the power supply using a personal computer. The library includes the QuickCharge class and methods: begin, which returns the adapter type; setMode, which sets the output voltage mode of the adapter - QC_5V, QC_9V, QC_12V, QC_20V, QC_VAR; and set, which sets the output voltage of the adapter in the QC_VAR mode.

QC_Remote program listing:

```
#define DP_H 4
#define DP_L 5
#define DM_H A4
#define DM_L A5

#include "QuickCharge.h"
QuickCharge QC (DP_H_PIN, DP_L_PIN, DM_H_PIN, DM_L_PIN, QC_CLASS_B);

void setup() {
  Serial.begin(9600);                 // open Serial port
  Serial.setTimeout(100);             // set the timeout
  // Information on the adapter type is displayed
  Serial.print(F("Charger type: "));
  // The begin method is called, which returns the adapter type
  int type = QC.begin();
  switch (type) {                 // the adapter type is displayed
    case QC_NA:   Serial.println(F("QC is not available")); break;
    case QC_GEN1: Serial.println(F("QC1.0 - (5V 2A)")); break;
    case QC_GEN2: Serial.println(F("QC2.0 or QC3.0")); break;
  }
  QC.setMode(QC_VAR);                 // voltage setting mode
```

```
22  }
23
24  void loop() {
25    /* Control of the output voltage through the Serial monitor, the voltage
26  is set in mV */
27    if (Serial.available() > 1) {      // there is a message on Serial
28      int mv = Serial.parseInt();      // voltage in mV
29      QC.set(mv);                      // the required voltage is set
30      Serial.print(F("Set voltage to: ")); // the voltage is output
31      Serial.print(QC.voltage());
32      Serial.println(F(" mV"));
33    }
34  }
```

The program enables remote control of the operation of the programmable power supply. To do this, you need to connect the control module to a Quick Charge-compatible power adapter and to a computer. Afterward, run the "QC_Remote" program in the Arduino IDE and input the desired output voltage in the Serial Monitor. Within 1 ms, the required output voltage will appear at the output of the programmable power supply.

3.7. Study of the QuickCharge-Based Programmable Power Supply

The Arduino Nano module was programmed with the QC_Remote program using the Arduino IDE. The Xiaomi MOY-11-EZ charger, Forever Core QC3.0 FC-01 22.5W Power Bank, RavPower PP-PC132 power adapter, InFinix XC02, USlion USR UD7656, Remax PD P-96 Power Bank, and Xiaomi Mi Power Bank 2 were used as test devices. The results of the QC protocol type determination are shown in Figure 10.

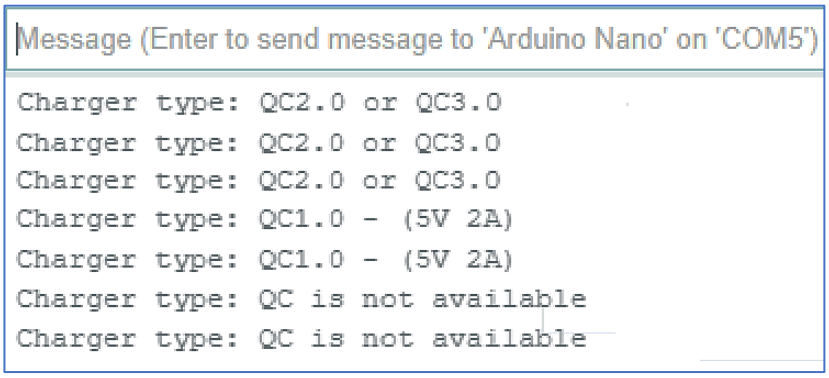

Figure 10: Determination of the Supported QC Protocol Type for Tested Power Adapters and Power Banks

Based on the QC protocol testing results, the Xiaomi MOY-11-EZ charger, RavPower PP-PC132 power adapter, and Forever Core QC3.0 FC-01 22.5W Power Bank can be used for further experiments. The results of experimental studies of the programmable power supply with remote control using the Xiaomi MOY-11-EZ charger are presented in Figure 11 and Figure 12. Remote control of the programmable power supply was conducted through the Serial Monitor in the Arduino IDE. The desired output voltage was entered in millivolts in the Message window. This message was sent to the Arduino Nano through COM5 and processed in the loop section (lines 24-34) of the QC_Remote program.

```
Message (Enter to send message to 'Arduino Nano' on 'COM5')

Charger type: QC2.0 or QC3.0
Set voltage to: 7000 mV
Set voltage to: 10000 mV
Set voltage to: 15000 mV
Set voltage to: 18400 mV
Set voltage to: 19000 mV
Set voltage to: 3600 mV
Set voltage to: 5000 mV
```

Figure 11: Results of Serial Monitor Messages in the Arduino IDE with Remote Control of the Programmable Power Supply based on the Xiaomi MOY-11-EZ charger

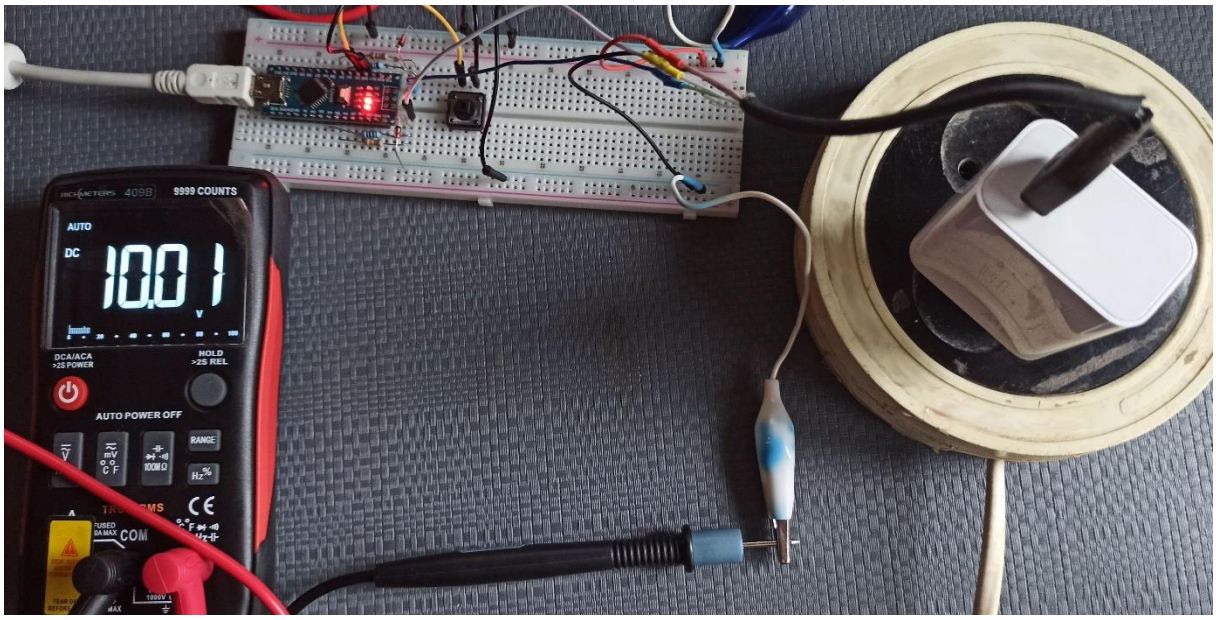

Figure 12: Experimental Study of the Operation of the Programmable Power Supply based on the Xiaomi MOY-11-EZ charger. Remote setting of the output voltage to 10V.

Remote control of the power supply through a wireless Wi-Fi interface can be implemented using the following methods [18, 19]: establish a connection between Arduino Nano and a Wi-Fi shield based on HDG04; establish a connection with Arduino Nano and ESP-01; use an IoT module based on the ESP8266/ESP32 chip, such as Node MCU V3, WeMos D1, Arduino Nano 33 IoT, or Arduino Nano RP2040. For remote control via Bluetooth interface, Bluetooth modules HC04-HC09 can be connected to the control module (Tx, Rx lines), or an Arduino Nano 33 BLE module can be used. Various adapters and converters into the UART interface are available for connecting to the control module using USB, RS-485, RS232, and CAN interfaces.

4. Acknowledgements

In this work, practical research on the implementation of a programmable power supply with remote control based on Quick Charge technology was conducted. The following conclusions can be drawn from the results:

1. Quick Charge 2.0 and 3.0 power adapters/chargers for mobile phones can be used to build a programmable power supply with remote control.
2. The output voltage can be remotely adjusted through the dedicated high-voltage Qualcomm charging port (HVDCP).

3. The control module is connected to the power adapter through HVDCP. The control module is powered either from a personal computer or from the power adapter. The remotely controlled output voltage is taken from the Vbus, Gnd lines (pins 1, 4) of the HVDCP port. Control of the output voltage is achieved through voltage levels of specific duration on the D+, D- lines of the HVDCP port.

4. The control module software allows for the detection of power adapters that support Quick Charge 2.0 and 3.0 technologies. Adapters with Quick Charge 2.0 can be switched to HVDCP discrete mode and have their output voltage remotely changed to fixed values of 5V, 9V, 12V, 20V. Adapters with Quick Charge 3.0 can be switched to HVDCP discrete and HVDCP continuous modes. HVDCP continuous mode allows remote control of the output voltage from 3.6V to 20V.

5. Remote control of the power supply can be achieved through the USB port, wireless Bluetooth, or Wi-Fi interfaces. The microcontroller of the control module must support a UART interface, to which shields, modules, or interface converters can be connected for interaction with remote control elements.

6. The software for remote control on the client side should be developed separately and should interact with the control module software.

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