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Introduction

Our main goal is to distinguish various types of light sources based on their color gamut response. From the previous experiments where we had studied color gamut response from different kinds of lamps (LED, RGB LED, HPS, Fluorescent etc.) we hypothesized that we might determine the type of streetlamp only by looking at their color gamut.

Figure 1 portrays how certain kinds of lamps fall into their region and based on in what region they are in, we might decide their type.

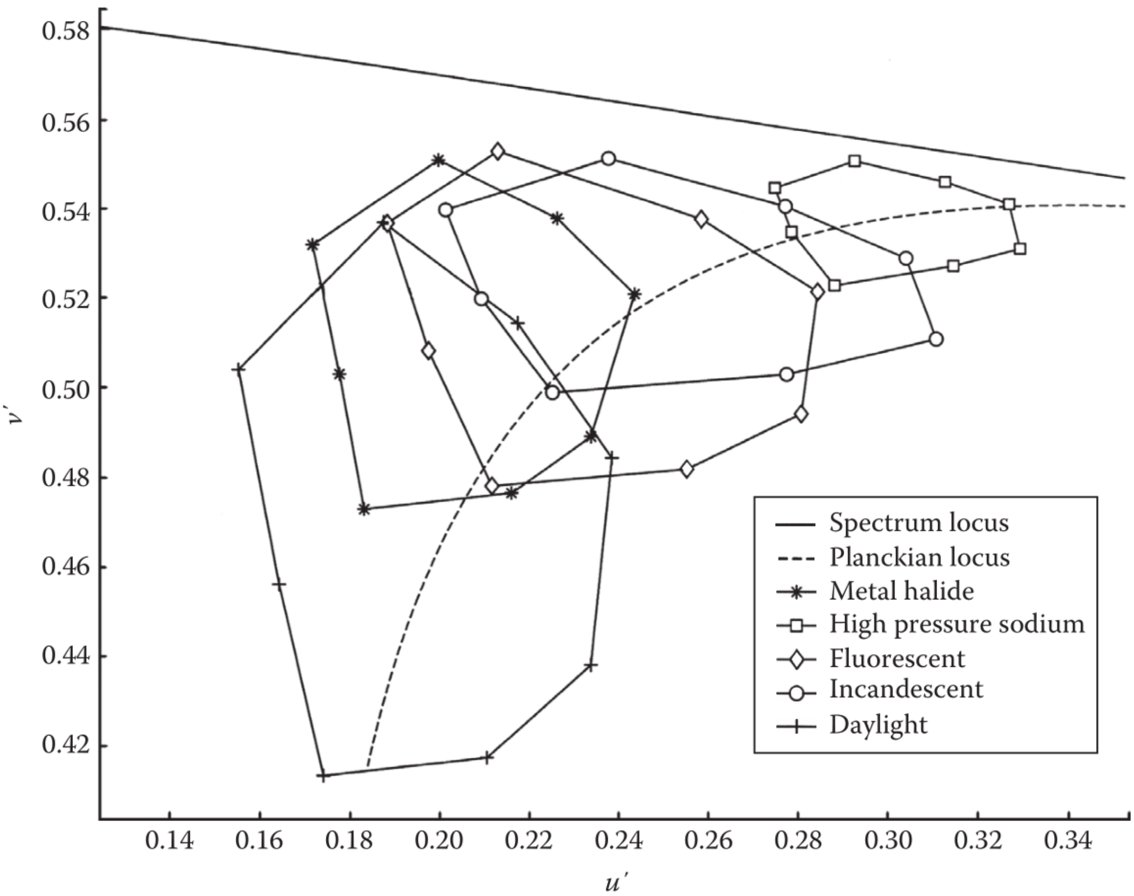


Figure 1 The color gamuts for high-pressure sodium (HPS), incandescent, fluorescent, and metal halide light sources, and for the CIE Standard Illuminant D65, simulating daylight, all plotted on the CIE 1976 UCS diagram. The dotted curve is the Planckian locus. (Boyce, 2014)

To test our hypothesis, firstly we would need to capture hundreds of responses from numerous light sources, which would be a tremendous job.

A method for capturing color gamut response is firstly capturing the radiating light from the light source with a digital camera and then calculate the so-called CIE chromaticity x and y and z coordinates based on the light source color. For the complete formulations, please see (Boyce, 2014).

We would like to have a device that contains numerous different monochromatic light sources. Device should turn every one of those light sources independently with user selectable light intensity.

1. Device

1.1. Requirements

Below is a list of requirements that the device must have:

- The device must contain an array of twenty two-leaded connectors to connect twenty different light sources (LEDs, Low-power lasers etc.).
- The device must have the ability to receive commands ether trough Universal Serial Bus (USB) or wirelessly with the Bluetooth protocol. Commands must be in a simple ASCII string form.
- Every command must specify what light source should be turned on and with what intensity.
- The board must be powered with conventional EU plug (230V, 60 Hz).

1.2. Principle of operation

Figure 2 portrays general functional block diagram. On the left side we have two communication ports: USB and Bluetooth. Both of those communication channels are bi-directional.

Between a communication ports and light-sources-array lays low-cost general-purpose microcontroller that acts as a bridge between the two. His function is to encode the user commands (which are human readable) into analog voltage and current that would drive each light-source.

Next to the microcontroller is light-source-array consisting of 20 different monochromatic light-sources. Every different light-source is physically swappable by the user.

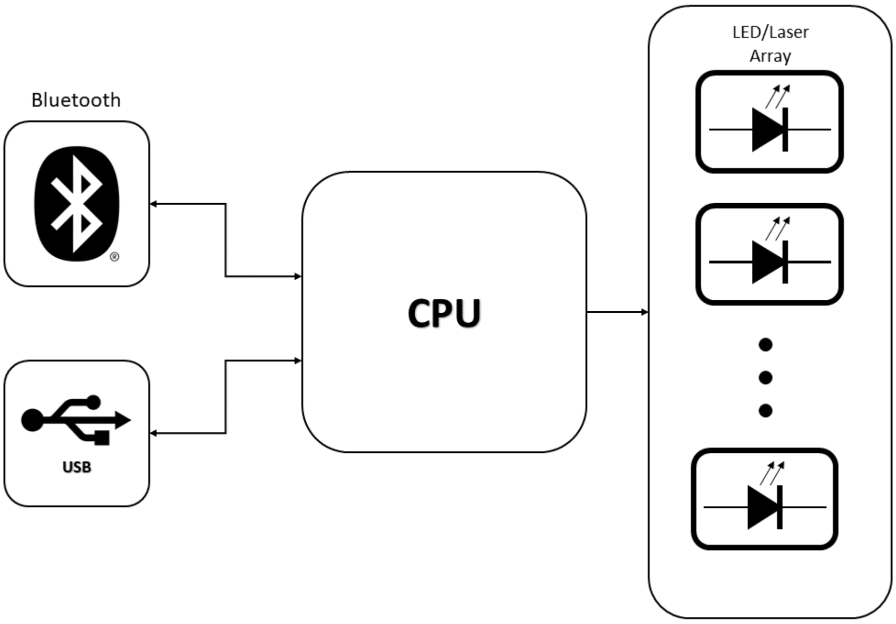


Figure 2 - Functional block diagram

1.2.1. Communication

Bluetooth

Bluetooth stack and communication protocol is vast topic by its own. As a result, we have chosen a system-on-chip solution (SOC) Bluetooth module. The module has the advantage over other Bluetooth solutions because the communication between two Bluetooth nodes goes over a UART protocol with an ASCII coded characters as data.

We intend to use rather famous between hobbyists AT-09 module. Other modules could also be of good use as long as they have the simple UART interface.

USB

For the USB side it is no different. Microcontroller has native support (both hardware and software) for USB communication. Data will be sent through established Virtual COM port emulation RS-232 serial communication in ASCII decoded characters.

1.2.2. CPU

For the CPU we chose general-purpose STM32F103 series microcontroller (MCU), which has all the functionalities we need: USB, USART, and two I^2C communication ports. Also, contains 64 KB Flash memory and 20 KB RAM, which is sufficient for our application (STMicroelectronics , 2020).

Functionality

The MCU receives commands through USB or Bluetooth, encodes them, and then sends them to the Light source array over I^2C communication. The latter part is explained later in details.

1.2.3. Light-source array

Overview

Figure 3 portrays the light-source array consisting of 20 independent LED or laser diodes where each light-source can be lit with its own amount of current.

The array consists of modules where every single module has analog circuitry that governs an amount of current and voltage of each diode.

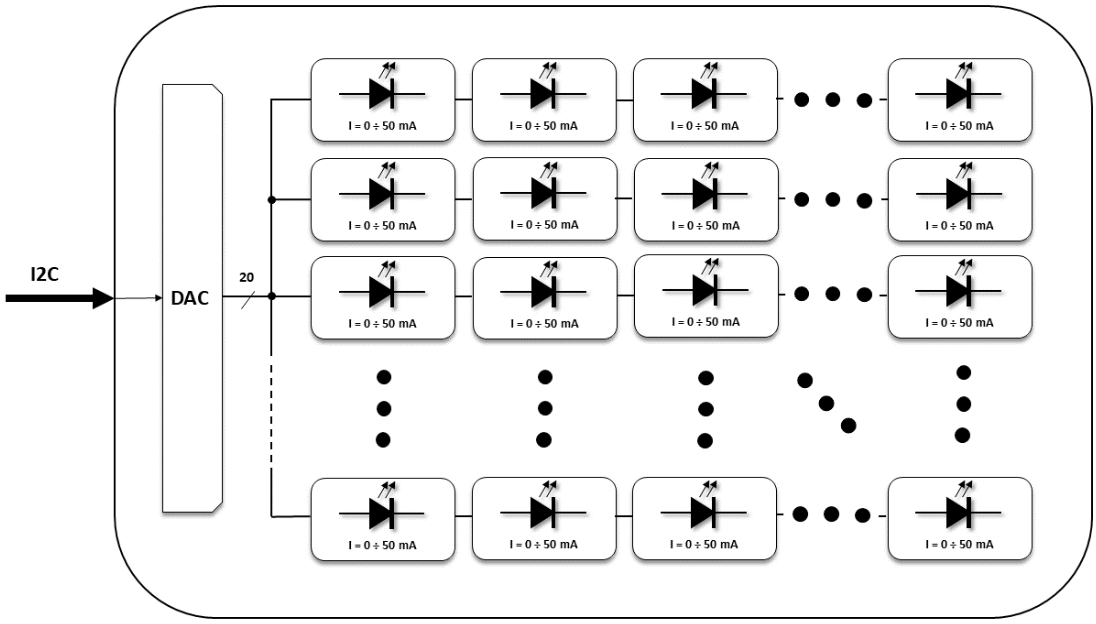


Figure 3 - Light-source array

Every cell consists of one Digital-to-analog converter (DAC), Operational amplifier (OP-AMP), MOSFET transistor, current-sense resistor, and one header connector for the diode (Figure 4).

Principle of operation

I_d is the desired current trough the diode ranging from 0 to 50 mA. This current creates voltage drop on the current-sense resistor R_s in the range from 0 to 5 volts. This voltage drop then goes to the OP-AMP which then compares the desired voltage (+ side) to the voltage drop across R_s resistor. The DAC output voltage ranges also from 0 to 5 volts. Based on the difference, OP-AMP drives the gate of the MOSFET which then regulates the current trough the diode by varying its drain-to-source voltage drop.

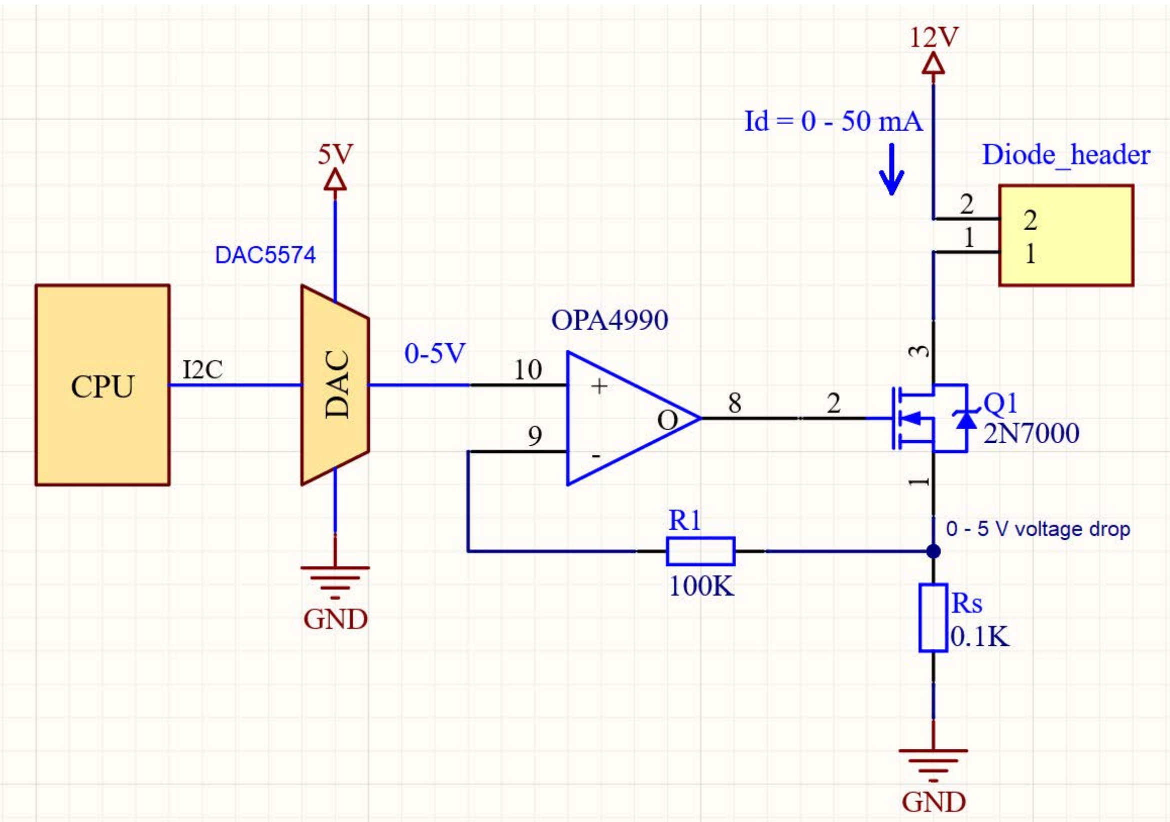


Figure 4 - Light-source array cell

DAC

The DAC5574 is a rail-to-rail, quad channel, 8-bit digital-to-analog converter (DAC) whose output voltage ranges from 0 to 5 volts. It consists of 4 DACs in one package in order to save printed-circuit board (PCB) space.

Least significant bit (LSB) of the DAC output is equivalent to:

$$\mathrm{U}_{LSB} = \frac{Uout}{2^{n\_bits}} = \frac{5\ \mathrm{V}}{256\ \mathrm{bit}} \cong 19.531\ \frac{\mathrm{mV}}{\mathrm{bit}}.$$

Communication with the DACs goes over an I^2C interface.

OP-AMP

For the OP-AMP, we chose OPA4990 general-purpose operational amplifier with rail-to-rail input/output. It consists of 4 OP-AMPs in one package in order to save PCB space.

The OP-AMP output is directly connected to a 2N7000 gate general-purpose, low-voltage, enhanced-mode MOSFET.

The OP-AMP short-circuit-input principle gives us the LSB diode current:

$$I_{d,LSB} = \frac{\mathrm{U}_{LSB}}{Rs} \cong \frac{19.531\ {}^{\mathrm{mV}}/_{\mathrm{bit}}}{100\ \Omega} \cong 0.1953\,\frac{\mathrm{mA}}{\mathrm{bit}}\ .$$

Therefore, with the 8-bit DAC output we have 0-50 mA current swing.

MOSFET

General-purpose 2N7000 MOSFET drives its drain-to-source voltage drop in order to set a desired current trough the diode specified by the OP-AMP.

Because of the low power-loss across the transistor, we have chosen TO-92 package.

Power supply voltage

We chose 12 Volts as the power supply voltage because it covers wide forward-voltage-drop range.

2. Usage

This section describes general procedures of using the device.

2.1. Power

Power supply

In order to power up the device, user must plug in main power plug into 230 V, 50 Hz EU electrical socket and then turn on the main power switch.

If there are no errors, the status LED should be blinking and the light-source array is completely turned off.

Fuses

To prevent the device from permanent electric damage user must install two different fuses. To install fuses user should firstly power off the device by unplugging it from the electrical grid and then open the box.

Into designated fuse holders, install two types of fuses:

- Slow blow, 40 A, 250 V for 12 V rail and,
- Slow blow, 20 A, 250 V for 9 V rail.

2.2. Light-source array

In order to place individual light sources, firstly turn the device off. Next, put two leads into their appropriate header paying attention about leads polarity.

After plugging the device on, the light-source array is automatically entirely turned off.

2.3. Communication

USB

In order to use USB communication, user should connect PC and a device with an USB 2.0 type B connector cable.

The device should appear on a PC as a virtual COM port. Communication with the device can be established via standard Serial port monitors.

Bluetooth

To use Bluetooth communication user must firstly establish a connection between two Bluetooth devices. After that, user should use standard Serial port monitors. Serial port monitors exist for both PC and mobile phones.

Commands

Commands could be sent using traditional Serial port monitors with a simple commands format explained below.

Commands format

In order to address every single light source, we have developed a command format which every user must follow. The format is explained below:

D_XX_YY.ZZ

Where:

- “D” is an ASCII character abbreviating the word *diode*,
- “XX” is a leading zero, two digit, natural number (e.g., 00, 01, 02 , … , 98 , 99) representing a diode ID and
- YY.ZZ is a leading zero, rational number (e.g., 00.00 , 00.01, … , 99.99) representing a current trough the light source in miliamperes (see Light-source array heading).

For example, if user wants to set a 3.52 mA current trough some arbitrary diode with an ID No. 7, user must send an ASCII command string:

Highest YY.ZZ diode current is 50.00 miliamperes by design. If user sends command with a higher current requirement, the command will be ignored. In order to turn off the diode, user should put 00.00 as the YY.ZZ value.

Diode ID numeration is shown in figure below. First ID (00) is in phisicly located in the upper-left corner. Next ID (01) is located next to it to the right side and so on.

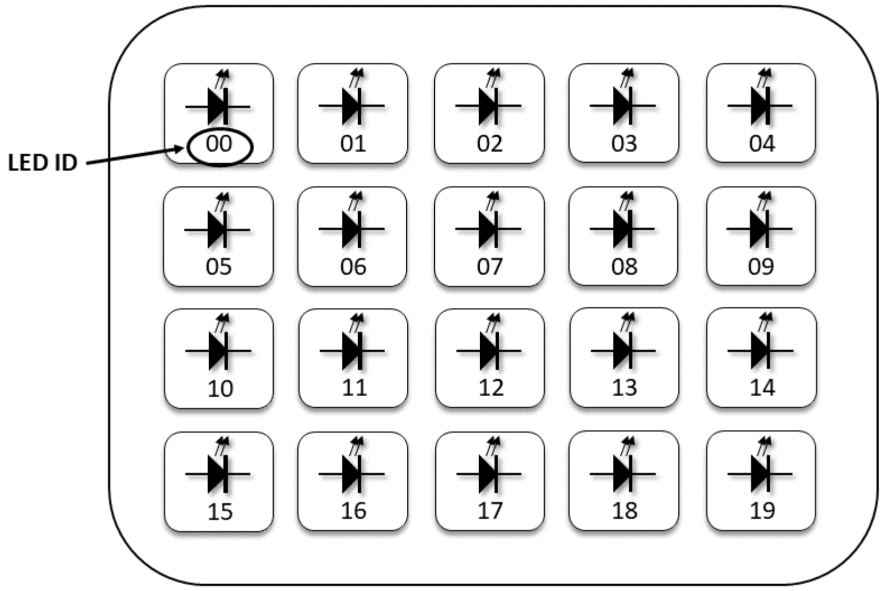


Figure 5 - Physical layout of the light-source array

Conclusion

asdasdsd

Literature

Boyce, P. R. (2014). *Human Factors in Lighting.* Boca Raton: CRC Press.

STMicroelectronics . (7. May 2020). *STMicroelectronics* . Preuzeto 7. May 2020 iz Microcontrollers & Microprocessors: https://www.st.com/en/microcontrollers-microprocessors/stm32f103.html

Texas Instruments. (n.d.). *Product page.* Preuzeto May 2020 iz DAC5574 product page: http://www.ti.com/product/DAC5574

Texas Instruments. (n.d.). *Products.* Preuzeto May 2020 iz OPA4990 product page: https://www.ti.com/product/OPA4990

Abstract

System for evaluating the color response of a digital camera sensor

Build a controllable light source comprising of a multiplicity of light-emitting diodes and semiconductor lasers covering the visible spectrum: from near infrared (1000 nm) to UVA (365 nm). The output intensity of the diodes/lasers should be remotely controllable via USB and/or Bluetooth. Demonstrate the use of the developed instrument to evaluate the color gamut of at least one digital camera sensor.

Sažetak (Croatian)

Sustav za evaluaciju odziva boje digitalne kamere

Izraditi izvor svjetla od više svjetlećih dioda i poluvodičkih lasera koji pokrivaju vidljivi dio spektra: od 1000 nm (infracrvena boja) do 365 nm (ultraljubičasta boja A). Intenzitet svjetla iz svake diode će se kontrolirati preko USB sučelja ili preko Bluetooth sučelja. Demonstrirati korištenje razvijenog uređaja za mjerenje gamuta barem jedne digitalne kamere.

Keywords

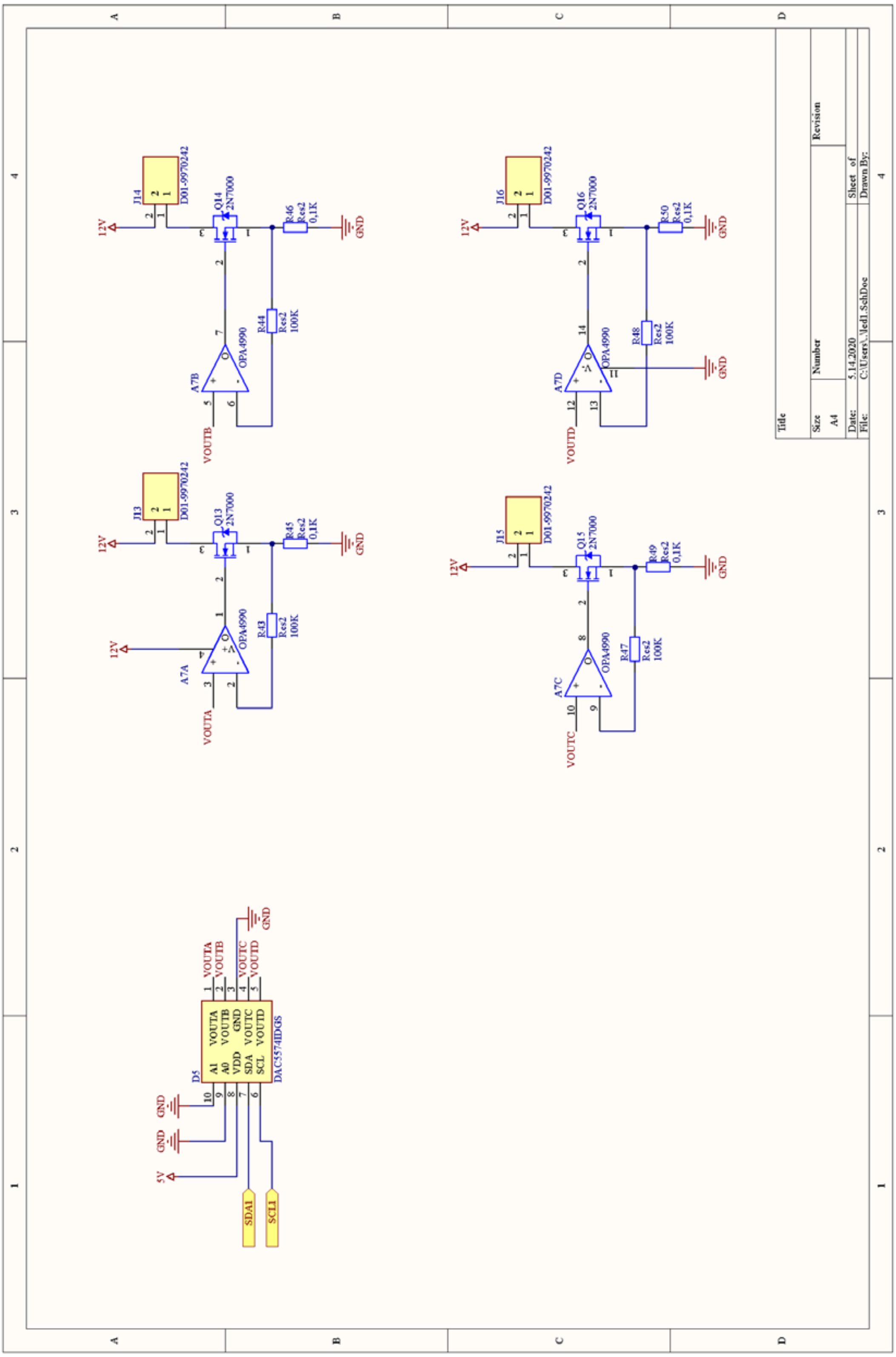
Ovo poglavlje nije obavezno, ali se može dodati radi preglednosti.

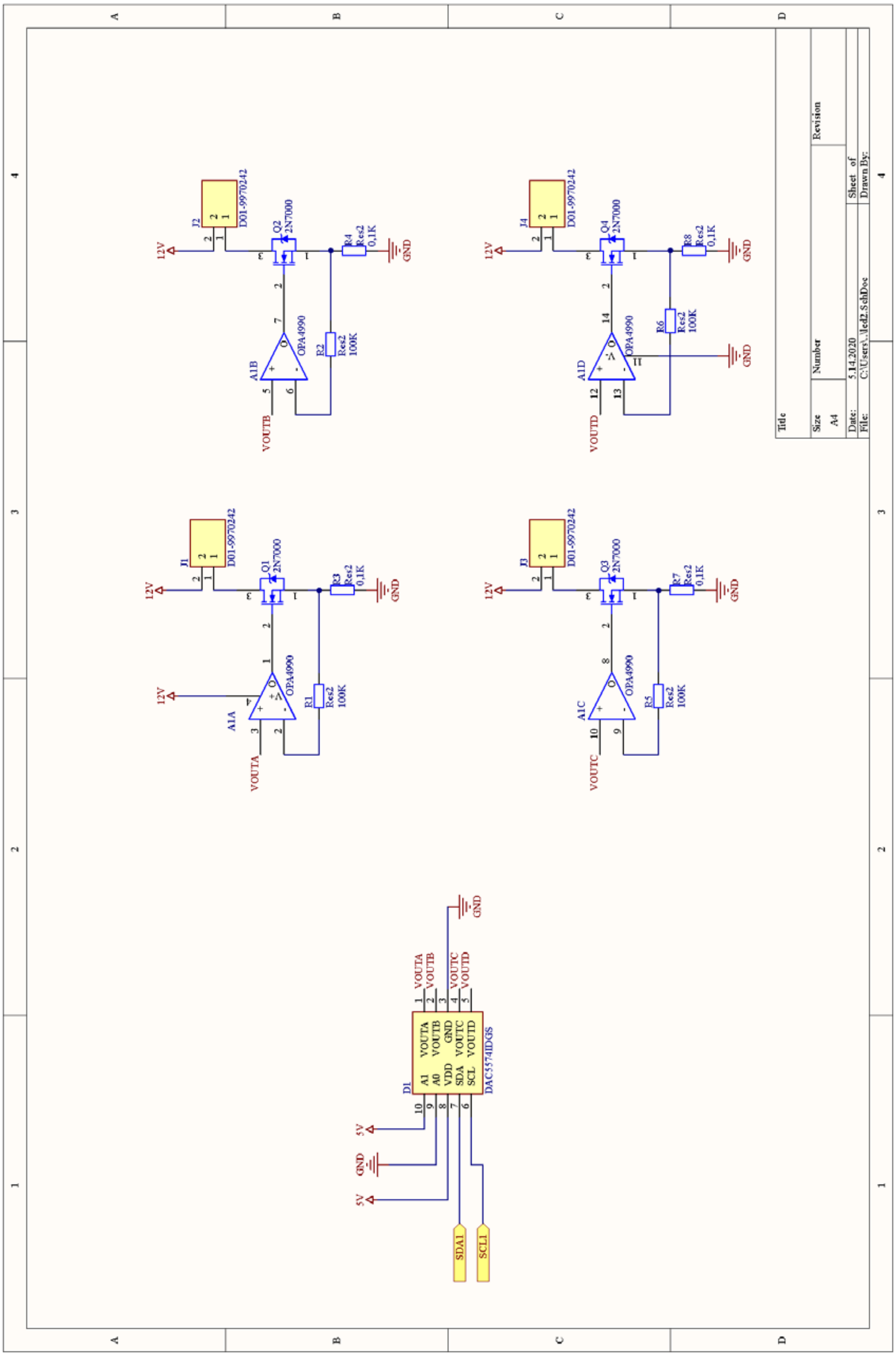
ATM	*Asynchronous Transfer Mode*	asinkroni način prijenosa
ISDN	*Integrated Services Digital Network*	digitalna mreža integriranih usluga

Napomena: na naslov **Skraćenice** primijenite stil Heading 1, a zatim ručno maknite brojčanu oznaku (to je važno kako bi i skraćenice ušle u sadržaj na početku rada, prije uvoda). Pri kreiranju popisa skraćenica koristite stil *nabrajanje*.

Appendix A: PCB documentation

A.1 Schematic sheet documents

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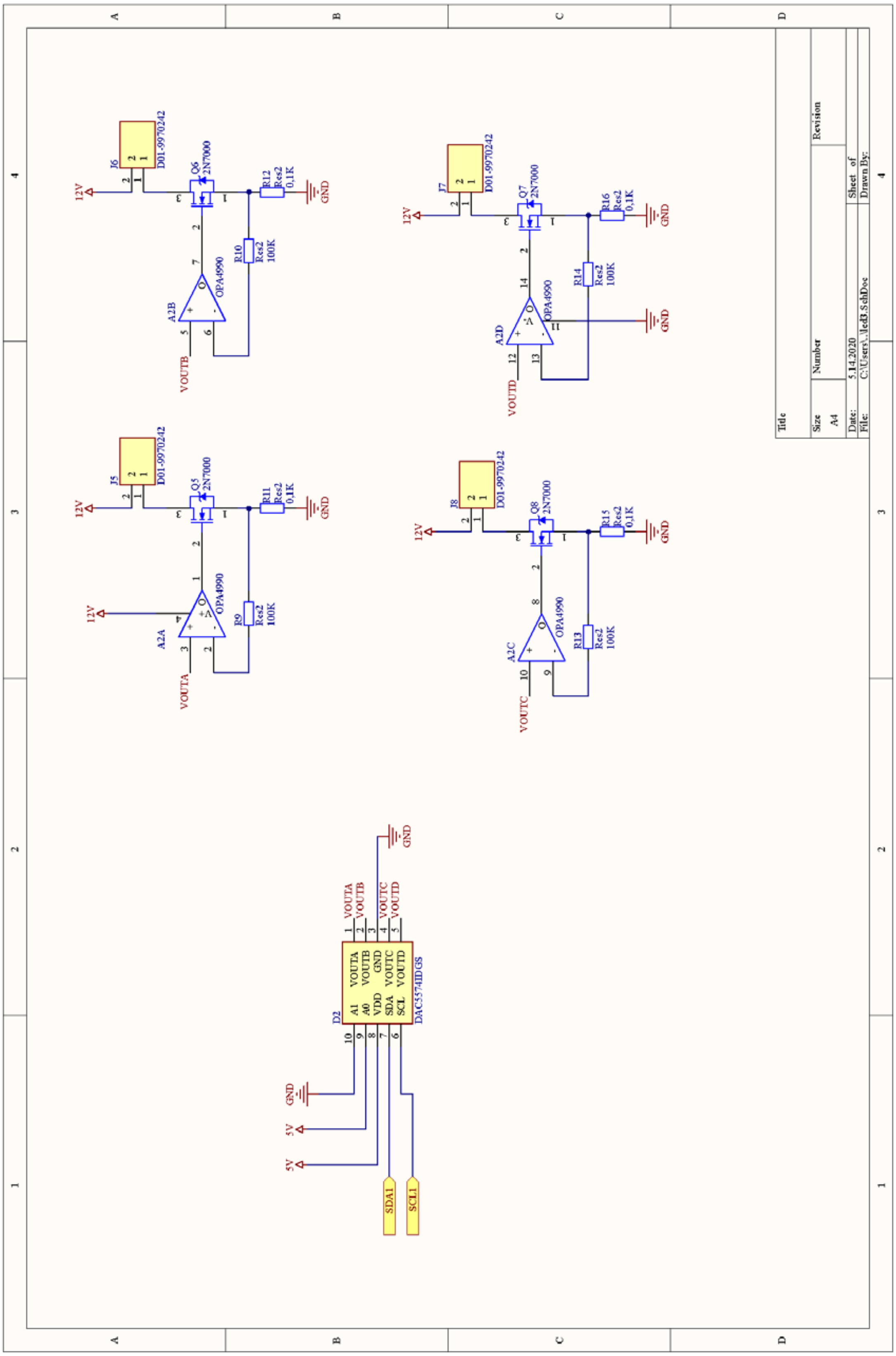
DAC5574IDGS
VOUTA
VOUTB
VOUTC
VOUTD
GND
5V
12V
SDA1
SCL1
A1A
A1B
A1C
A1D
OPA4990
Q1
Q2
Q3
Q4
2N7000
J1
J2
J3
J4
D01-9970242
Res2
100K
0,1K
Title
Size
A4
Number
Revision
Date:
5.14.2020
Sheet of
File:
Drawn By:



J5
J6
J7
J8
D01-9970242
Q5
Q6
Q7
Q8
2N7000
R9
R10
R11
R12
R13
R14
R15
R16
Res2
100K
0,1K
A2A
A2B
A2C
A2D
OPA4990
12V
GND
5V
VOUTA
VOUTB
VOUTC
VOUTD
D2
DAC5574IDGS
A1
A0
VDD
SDA
SCL
SDA1
SCL1
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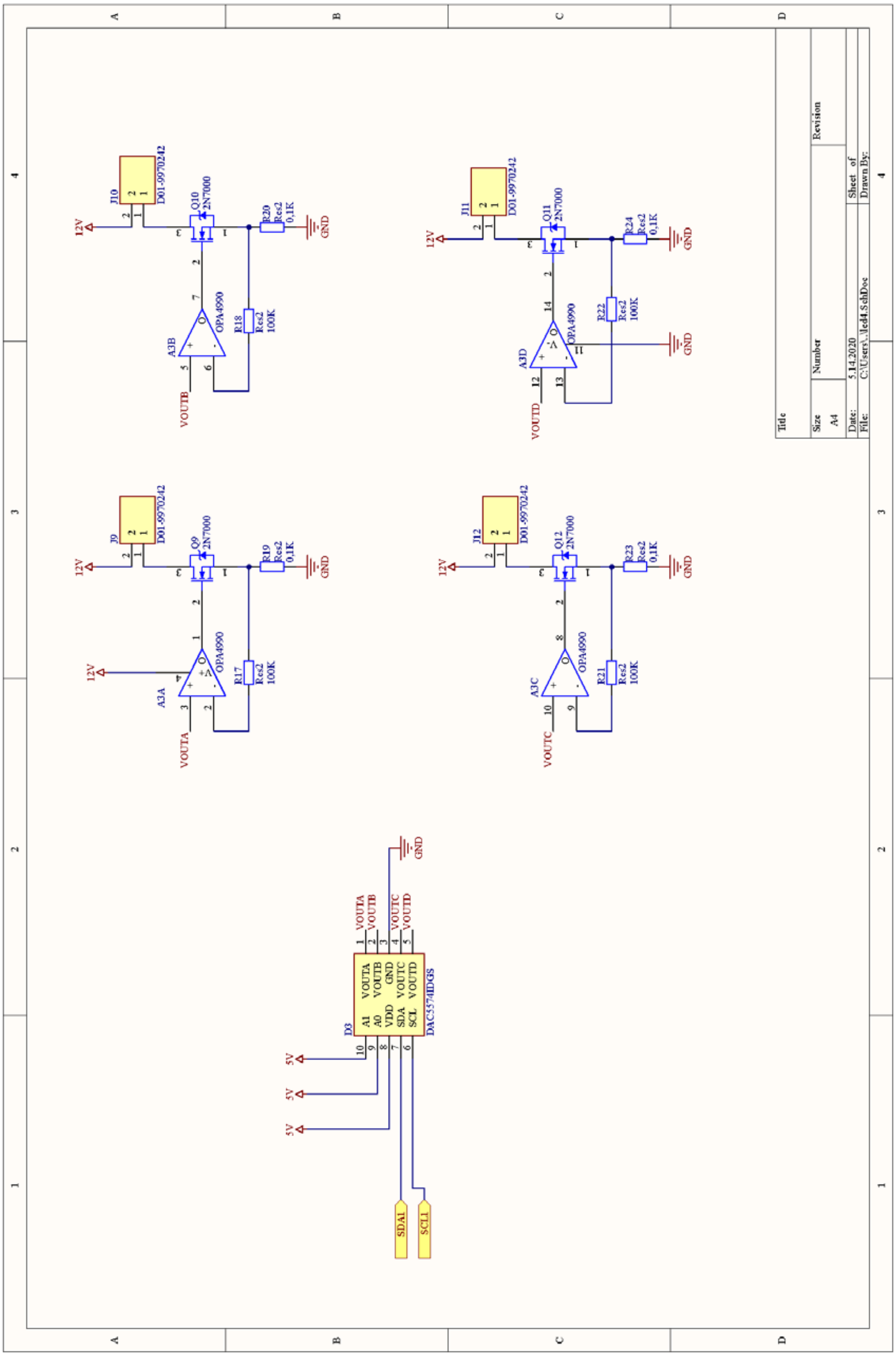

DAC5574IDGS
D3
VOUTA
VOUTB
VOUTC
VOUTD
GND
5V
12V
SDA1
SCL1
A3A
A3B
A3C
A3D
OPA4990
2N7000
D01-9970242
Res2
100K
0,1K
Title
Size
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Number
Revision
Date:
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File:
Sheet of
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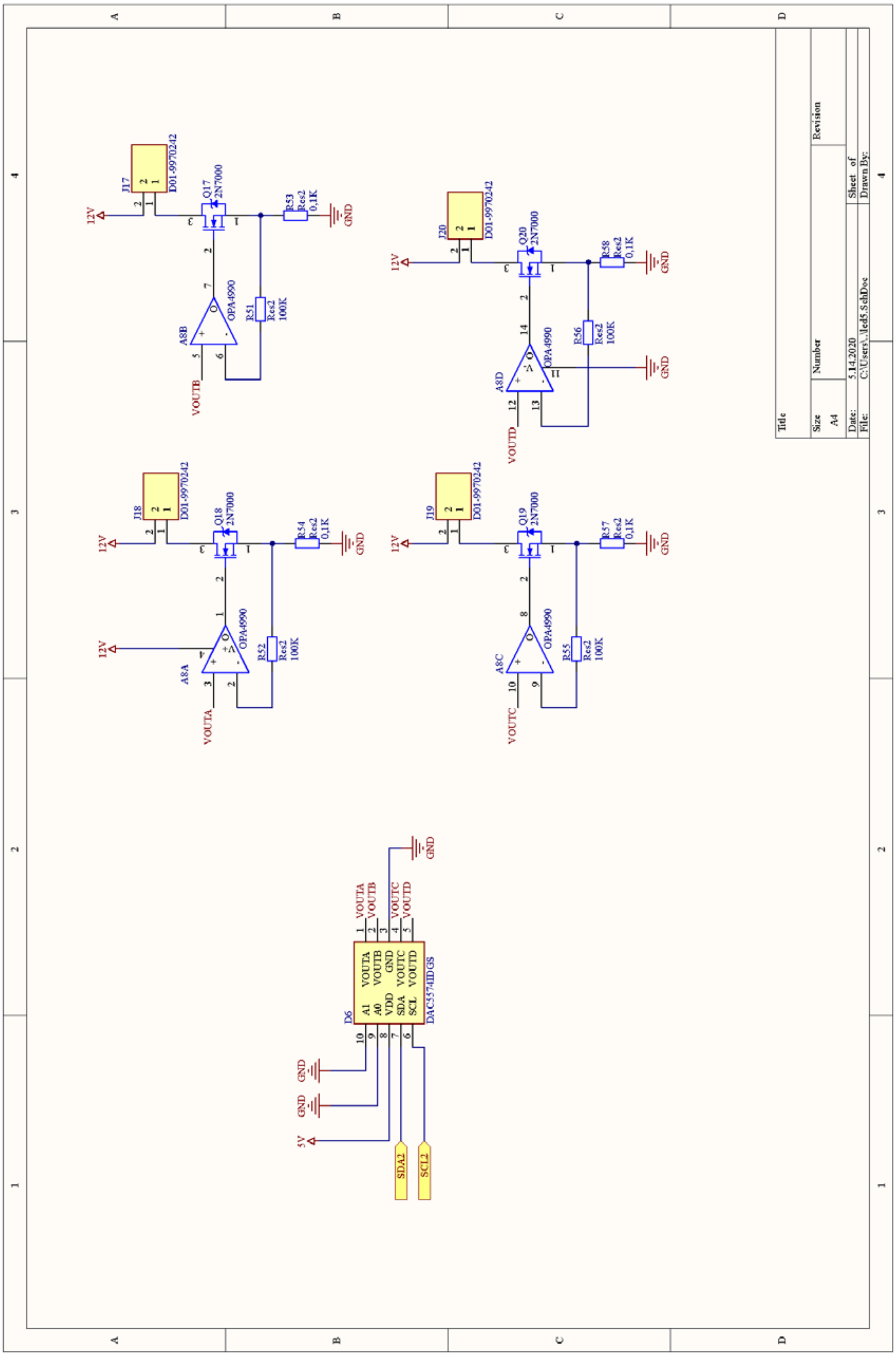

J17
J18
J19
J20
D01-99702242
Q17
Q18
Q19
Q20
2N7000
A8A
A8B
A8C
A8D
OPA4990
R51
R52
R53
R54
R55
R56
R57
R58
Res2
100K
0,1K
12V
GND
5V
VOUTA
VOUTB
VOUTC
VOUTD
D6
DAC5574IDGS
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A0
VDD
SDA
SCL
SDA2
SCL2
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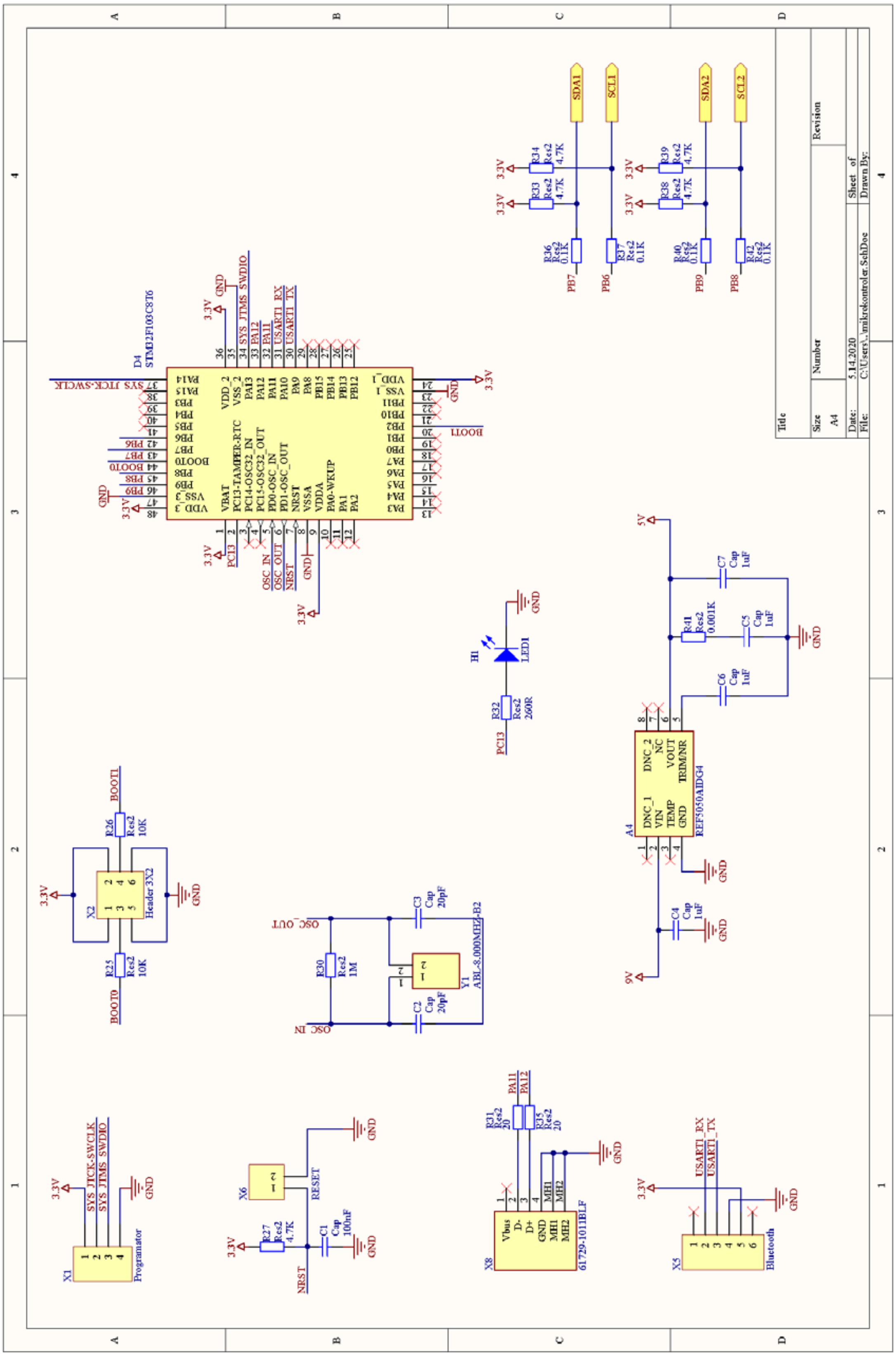
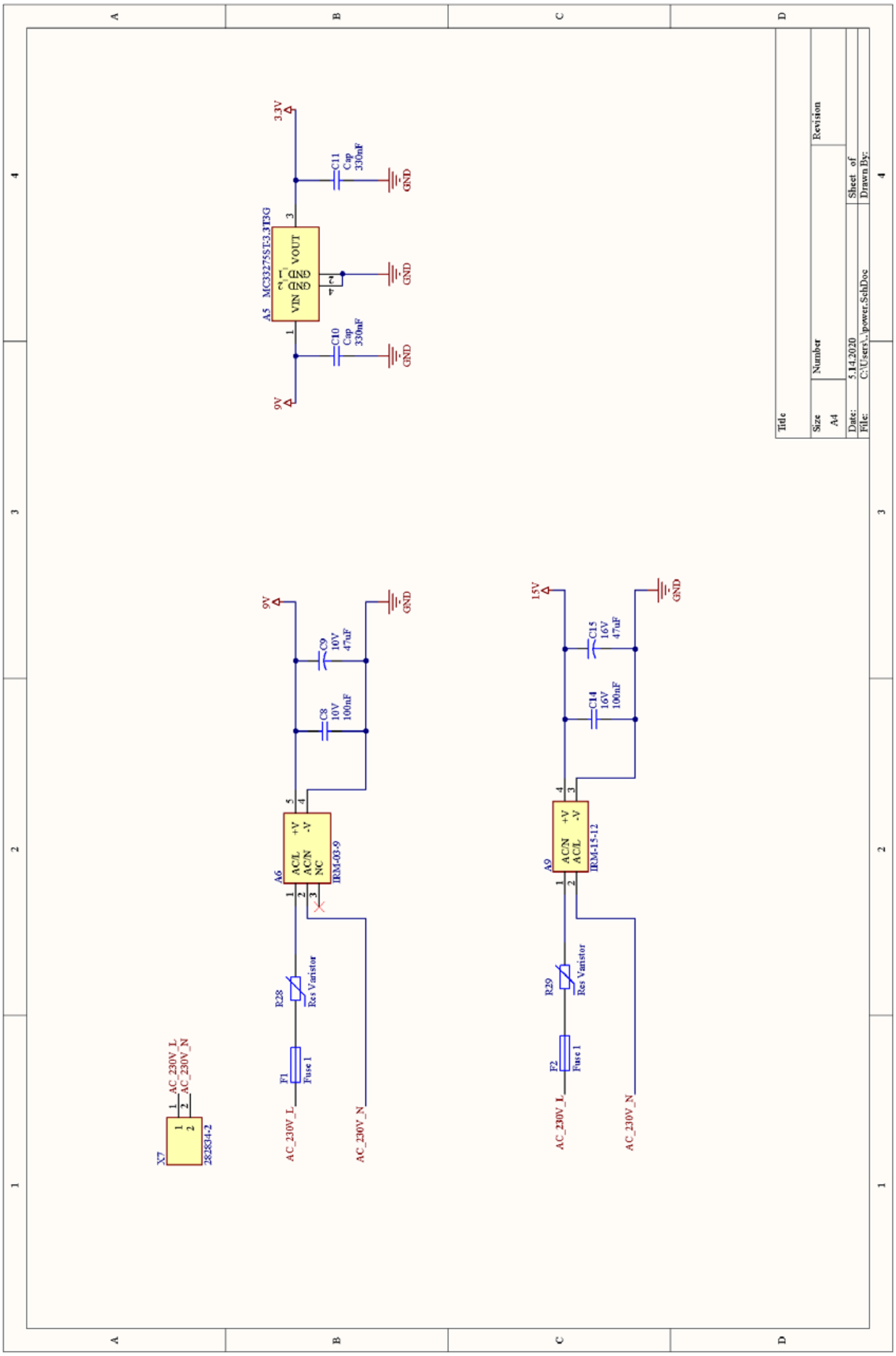


STM32F103C8T6
REF5050AIDG4
61729-1011BLF
Programator
Bluetooth
Header 3X2
ABL-8.000MHZ-B2



A
B
C
D
1
2
3
4
3.3V
C11
Cap
330nF
GND
A5
MC33275ST-3.3T3G
VIN
GND
GND
VOUT
C10
Cap
330nF
9V
C9
10V
47uF
C8
10V
100nF
A6
AC/L
AC/N
NC
+V
-V
IRM-03-9
R28
Res Varistor
F1
Fuse 1
AC_230V_L
AC_230V_N
X7
282834-2
15V
C15
16V
47uF
C14
16V
100nF
A9
AC/N
AC/L
IRM-15-12
R29
F2
Title
Size
A4
Number
Revision
Date:
5.14.2020
Sheet of
File:
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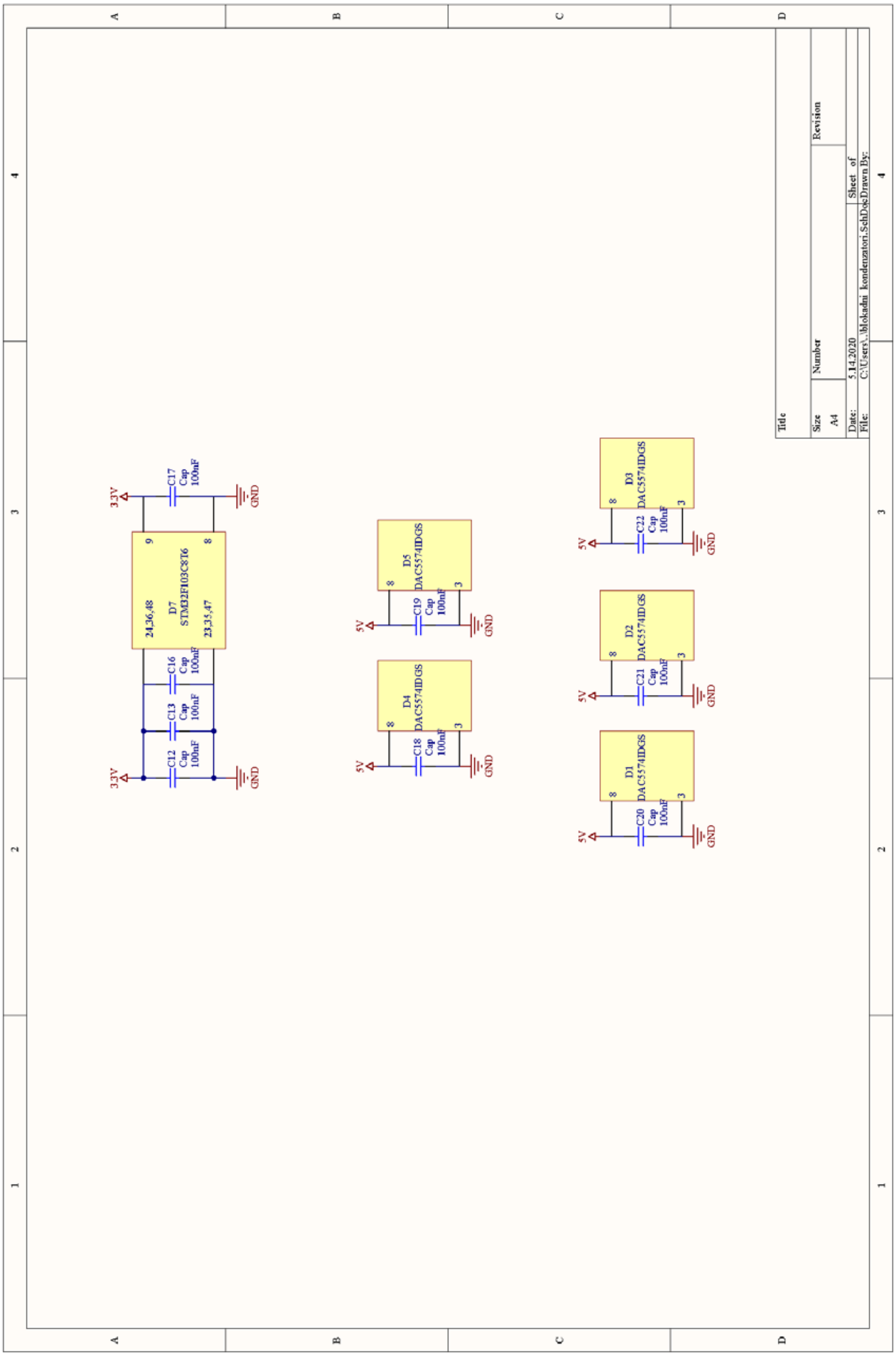
Drawn By:


D7
STM32F103C8T6
24,36,48
23,35,47
9
8
C12
C13
C16
C17
Cap
100nF
3.3V
GND
D1
D2
D3
D4
D5
DAC5574IDGS
C18
C19
C20
C21
C22
5V
Title
Size
A4
Number
Revision
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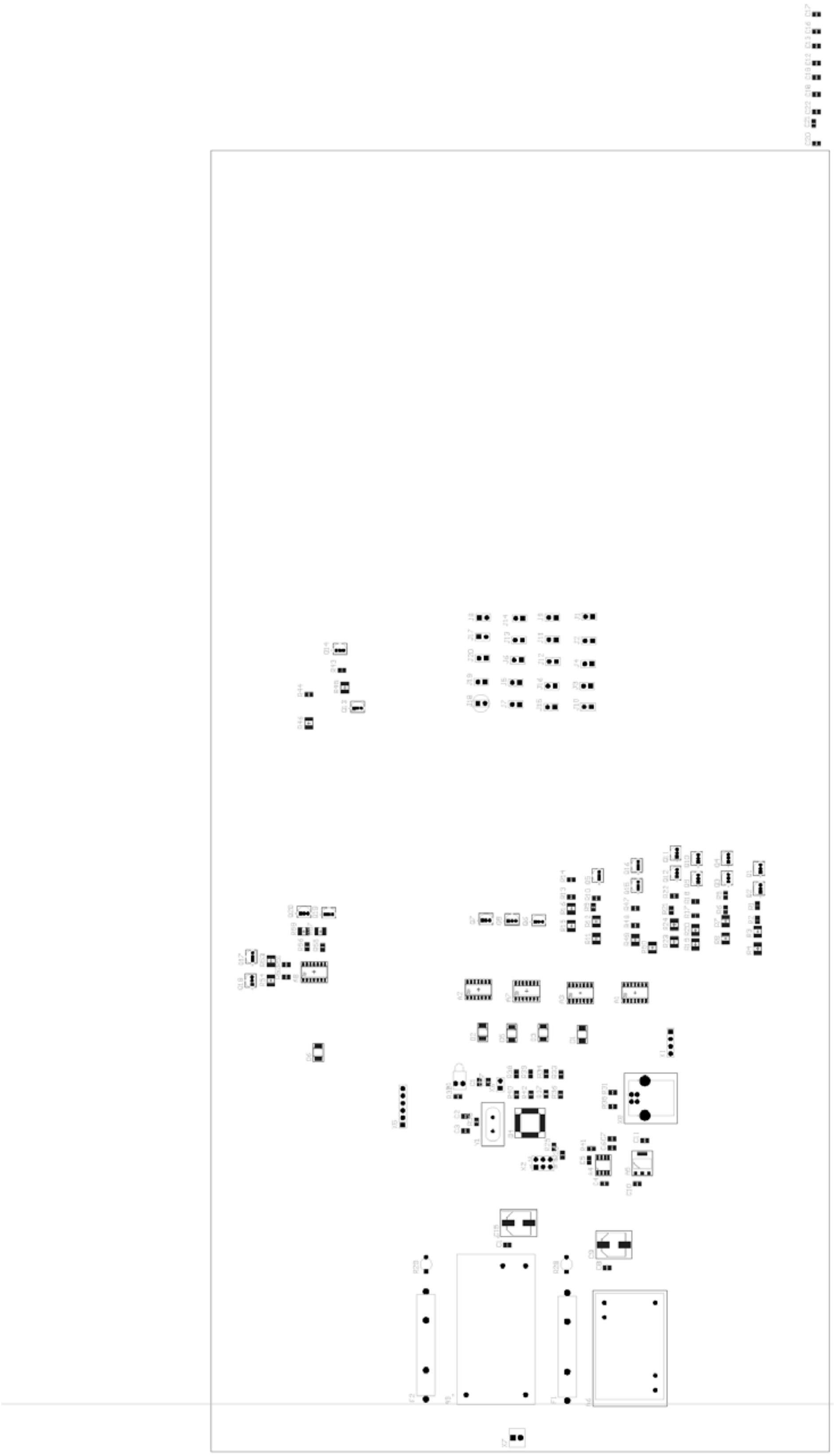
A.2 PCB layout



Appendix B: Datasheets

B.1 STM32F103C8T6 microcontroller

life.augmented

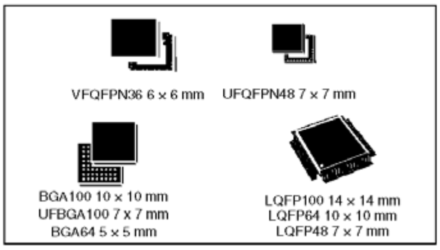
STM32F103x8
STM32F103xB

Medium-density performance line ARM®-based 32-bit MCU with 64 or 128 KB Flash, USB, CAN, 7 timers, 2 ADCs, 9 com. interfaces

Datasheet - production data

Features

- ARM® 32-bit Cortex®-M3 CPU Core
  - 72 MHz maximum frequency, 1.25 DMIPS/MHz (Dhrystone 2.1) performance at 0 wait state memory access
  - Single-cycle multiplication and hardware division
- Memories
  - 64 or 128 Kbytes of Flash memory
  - 20 Kbytes of SRAM
- Clock, reset and supply management
  - 2.0 to 3.6 V application supply and I/Os
  - POR, PDR, and programmable voltage detector (PVD)
  - 4-to-16 MHz crystal oscillator
  - Internal 8 MHz factory-trimmed RC
  - Internal 40 kHz RC
  - PLL for CPU clock
  - 32 kHz oscillator for RTC with calibration
- Low-power
  - Sleep, Stop and Standby modes
  - V_{BAT} supply for RTC and backup registers
- 2 x 12-bit, 1 μs A/D converters (up to 16 channels)
  - Conversion range: 0 to 3.6 V
  - Dual-sample and hold capability
  - Temperature sensor
- DMA
  - 7-channel DMA controller
  - Peripherals supported: timers, ADC, SPIs, I^2Cs and USARTs
- Up to 80 fast I/O ports
  - 26/37/51/80 I/Os, all mappable on 16 external interrupt vectors and almost all 5 V-tolerant



- Debug mode
  - Serial wire debug (SWD) & JTAG interfaces
- 7 timers
  - Three 16-bit timers, each with up to 4 IC/OC/PWM or pulse counter and quadrature (incremental) encoder input
  - 16-bit, motor control PWM timer with dead-time generation and emergency stop
  - 2 watchdog timers (Independent and Window)
  - SysTick timer 24-bit downcounter
- Up to 9 communication interfaces
  - Up to 2 x I^2C interfaces (SMBus/PMBus)
  - Up to 3 USARTs (ISO 7816 interface, LIN, IrDA capability, modem control)
  - Up to 2 SPIs (18 Mbit/s)
  - CAN interface (2.0B Active)
  - USB 2.0 full-speed interface
- CRC calculation unit, 96-bit unique ID
- Packages are ECOPACK®

Table 1. Device summary

Reference	Part number
STM32F103x8	STM32F103C8, STM32F103R8 STM32F103V8, STM32F103T8
STM32F103xB	STM32F103RB STM32F103VB, STM32F103CB, STM32F103TB

August 2015 DocID13587 Rev 17 1/117

This is information on a product in full production. www.st.com

B.2 DAC5574 DAC

TEXAS INSTRUMENTS
www.ti.com

DAC5574

SLAS407 – DECEMBER 2003

QUAD, 8-BIT, LOW-POWER, VOLTAGE OUTPUT, I^2C INTERFACE DIGITAL-TO-ANALOG CONVERTER

FEATURES

- ***Micro*power Operation: 500 μA at 3 V V_{DD}**
- **Fast Update Rate: 188 kSPS**
- **Per-channel Power-down Capability**
- **Power-On Reset to Zero**
- **2.7-V to 5.5-V Analog Power Supply**
- **8-bit Monotonic**
- **I^2C™ Interface Up to 3.4 Mbps**
- **Data Transmit Capability**
- **On-Chip Output Buffer Amplifier, Rail-to-Rail Operation**
- **Double-Buffered Input Register**
- **Address Support for up to Four DAC5574s**
- **Synchronous Update Support for up to 16 Channels**
- **Operation From –40°C to 105°C**
- **Small 10 Lead MSOP Package**

APPLICATIONS

- **Process Control**
- **Data Acquisition Systems**
- **Closed-Loop Servo Control**
- **PC Peripherals**
- **Portable Instrumentation**

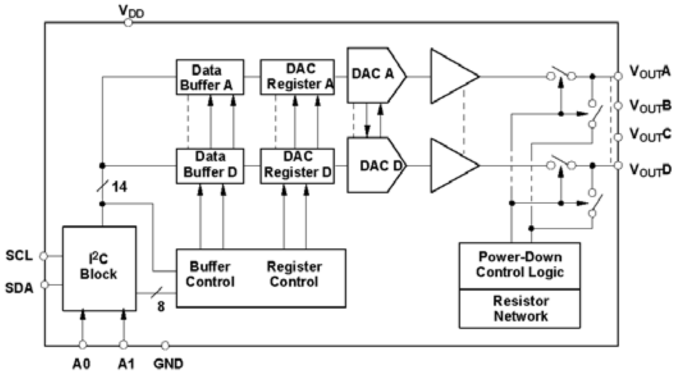
DESCRIPTION

The DAC5574 is a low-power, quad channel, 8-bit buffered voltage output DAC. Its on-chip precision output amplifier allows rail-to-rail output swing to be achieved. The DAC5574 utilizes an I^2C compatible two wire serial interface supporting high-speed interface mode with address support of up to four DAC5574s for a total of 16 channels on the bus.

The DAC5574 uses V_{DD} and GND to set the output range of the DAC. The DAC5574 incorporates a power-on-reset circuit that ensures that the DAC output powers up at zero volts and remains there until a valid write takes place to the device. The DAC5574 contains a per-channel power-down feature, accessed via the internal control register, reducing the current consumption of the device to 200 nA at 5 V.

The low power consumption of this part in normal operation makes it ideally suited to portable battery operated equipment. The power consumption is less than 3mW at V_{DD} = 5 V reducing to 1 μW in power-down mode.

TI offers a variety of data converters with I^2C interface. See DACx57x family of 16/12/10/8 bit, single and quad channel DACs. Also see ADS7823 and ADS1100, 12-bit octal channel and 16-bit single channel ADCs.



B.3 OPA4490 OP-AMP

Product Folder | Order Now | Technical Documents | Tools & Software | Support & Community

OPAx990 40-V Rail-to-Rail Input/Output, Low Offset Voltage, Low Power Op Amp

1 Features

- Low offset voltage: ±300 µV
- Low offset voltage drift: ±0.6 µV/°C
- Low noise: 30 nV/√Hz at 1 kHz
- High common-mode rejection: 115 dB
- Low bias current: ±10 pA
- Rail-to-rail input and output
- MUX-friendly/comparator inputs
  - Amplifier operates with differential inputs up to supply rail
  - Amplifier can be used in open-loop or as comparator
- Wide bandwidth: 1.1-MHz GBW
- High slew rate: 4.5 V/µs
- Low quiescent current: 120 µA per amplifier
- Wide supply: ±1.35 V to ±20 V, 2.7 V to 40 V
- Robust EMIRR performance: 78 dB at 1.8 GHz
- Differential and common-mode input voltage range to supply rail

2 Applications

- Multiplexed data-acquisition systems
- Test and measurement equipment
- Motor drive: power stage and control modules
- Power delivery: UPS, server, and merchant network power
- ADC driver and reference buffer amplifier
- Programmable logic controllers
- Analog input and output modules
- High-side and low-side current sensing
- High precision comparator

3 Description

The OPAx990 family (OPA990, OPA2990, and OPA4990) is a family of high voltage (40-V) general purpose operational amplifiers. These devices offer excellent DC precision and AC performance, including rail-to-rail input/output, low offset (±300 µV, typ), and low offset drift (±0.6 µV/°C, typ).

Unique features such as differential and common-mode input voltage range to the supply rail, high short-circuit current (±80 mA), high slew rate (4.5 V/µs), and shutdown make the OPAx990 an extremely flexible, robust, and high-performance op amp for high-voltage industrial applications.

The OPAx990 family of op amps is available in *micro*-size packages (such as X2QFN, WSON, and SOT-553), as well as standard packages (such as SOT-23, SOIC, and TSSOP), and is specified from –40°C to 125°C.

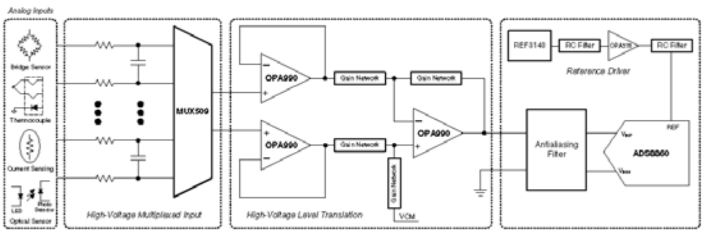
Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
OPA990	SOT-23 (5)	2.90 mm × 1.60 mm
	SOT-23 (6)	2.90 mm × 1.60 mm
	SC70 (5)	2.00 mm × 1.25 mm
	SOT-553 (5)(2)	1.60 mm × 1.20 mm
OPA2990	SOIC (8)	4.90 mm × 3.90 mm
	SOT-23 (8)(2)	2.90 mm × 1.60 mm
	TSSOP (8)	3.00 mm × 4.40 mm
	VSSOP (8)(2)	3.00 mm × 3.00 mm
	WSON (8)	2.00 mm × 2.00 mm
	X2QFN (10)(2)	2.00 mm × 1.50 mm
OPA4990	SOIC (14)	8.65 mm × 3.90 mm
	TSSOP (14)	5.00 mm × 4.40 mm
	WQFN (16)(2)	3.00 mm × 3.00 mm
	X2QFN (14)(2)	2.00 mm × 2.00 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

(2) This package is preview only.

OPAx990 in a High-Voltage, Multiplexed, Data-Acquisition System



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