Nixie Tube Clock

Datasheet

Revision 2

1 About This Document

This documentation describes the functionality and provides a technical overview of the Nixie Tube Clock.

2 Revision History and Changelog

16/1/2021: Revision 1 created.

[REDACTED]

3/2/2021: Revision 2 created.

[REDACTED]

3 Overview

The Nixie Tube Clock (henceforth referred to as “NTC”) is designed as an Internet + BLE connected (“IoT”) non-alarm clock with six base-10 cold-cathode numeric display tubes. The NTC integrates all three power supplies (including a high voltage supply for the cold-cathode tubes), GPIO multiplexers, darlington driver arrays, ESP32 System-On-Chip (SoC), high precision battery-backed RTC, temperature/humidity sensor, accelerometer and addressable RGB (ARGB) LEDs.
The NTC is to be powered from an external 12V (10%) supply rated at 1 amp minimum.

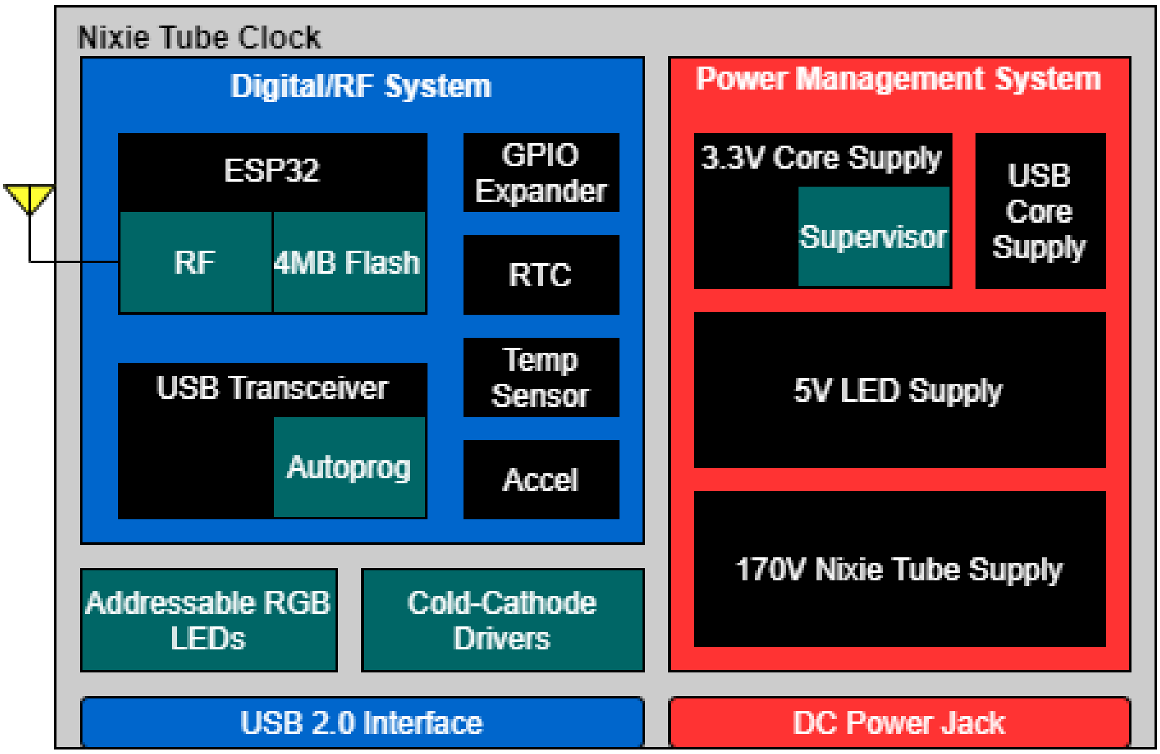


Figure 1: NTC Functional Block Diagram

4 Hardware Specifications

4.1 Absolute Maximum Ratings

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
Supply Voltage, V_{DD}		-0.3	20	V
Device Temperature	Limited by RTC battery	-10	65	°C
Maximum ESD Rating	At USB port, IEC 61000-4-2 Contact Discharge Level 4	-30000	30000	V

The device is not guaranteed to function within these ratings. Exceeding these ratings may cause permanent damage to the device. All voltages measured with respect to V_{ss}.

4.2 Recommended Operating Conditions

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
Supply Voltage, V_{DD}		10.5	15	V
Operating Temperature		0	40	°C
Operating Humidity	Non-condensing	0	90	%

All voltages measured with respect to V_{ss}.

4.3 Operating Characteristics

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Average Power Consumption, IDLE	BLE active, LEDs off, display off		0.6		W
Average Power Consumption, ACTIVE	BLE active, LEDs on, display on		9		W
Rated Supply Current, V170				100	mA
170V Line Regulation				1.6	%/V
170V Load Regulation				3	%/A
Supply Current, 3V3*				2	A
Supply Current, 5V				2	A

3V3, 5V Line Regulation*			0.002		%/V
3V3, 5V Load Regulation*			0.12		%/A
Minimum Digit On-Time	Cold start	50			µs
Wi-Fi Transmit Power	11b	18.5		20.5	dBm
Wi-Fi Receive Sensitivity	11b		-88		dBm
BLE Transmit Power		-12		9	dBm
BLE Receive Sensitivity			-93		dBm

Tests not conducted for 3V3 (USB) regulator.

5 System Description

5.1 Mainboard Functional Description

The NTC is designed around a single Printed Circuit Board (PCB) Mainboard which integrates all of the functionality described in Section 3. Sections 5.1.1 through 5.1.3 describe the mainboard functions in detail.

5.1.1 Digital/RF System

The NTC digital/RF system comprises of a ESP32 SoC with 4MB external flash, USB transceiver, 2 I2C GPIO expanders, accelerometer, temperature/humidity sensor and RTC as shown in Figure 2 below. The digital/RF system is powered from the 3V3 rail as mentioned in Section 5.1.2.

The internal pinout of the ESP32 SoC is listed in Table 1 below as reference for software development.

ESP32 Pin	Connection Name	Description
0	BOOT	Boot mode selector
1	TXD	USB transceiver TX
2	INT_RTC	RTC interrupt
3	RXD	USB transceiver RX
4	nEN170V	Active low 170V rail enable
5	INT_ACC	Accelerometer interrupt
6-11	N.A.	Internal SPI flash connections
16	EN5V	Active high 5V rail enable
17	nFAIL5V	Active low 5V rail power fail indicator
18	SCL	I2C bus clock
19	SDA	I2C bus data
21	ADDRLED	Addressable LED data pin
23	OPRLED	Operation LED indicator
25	DEVLED	Device LED indicator
26	PWRLED	Power LED indicator
27	COMLED	Communication LED indicator

Table 1: ESP32 Pinouts

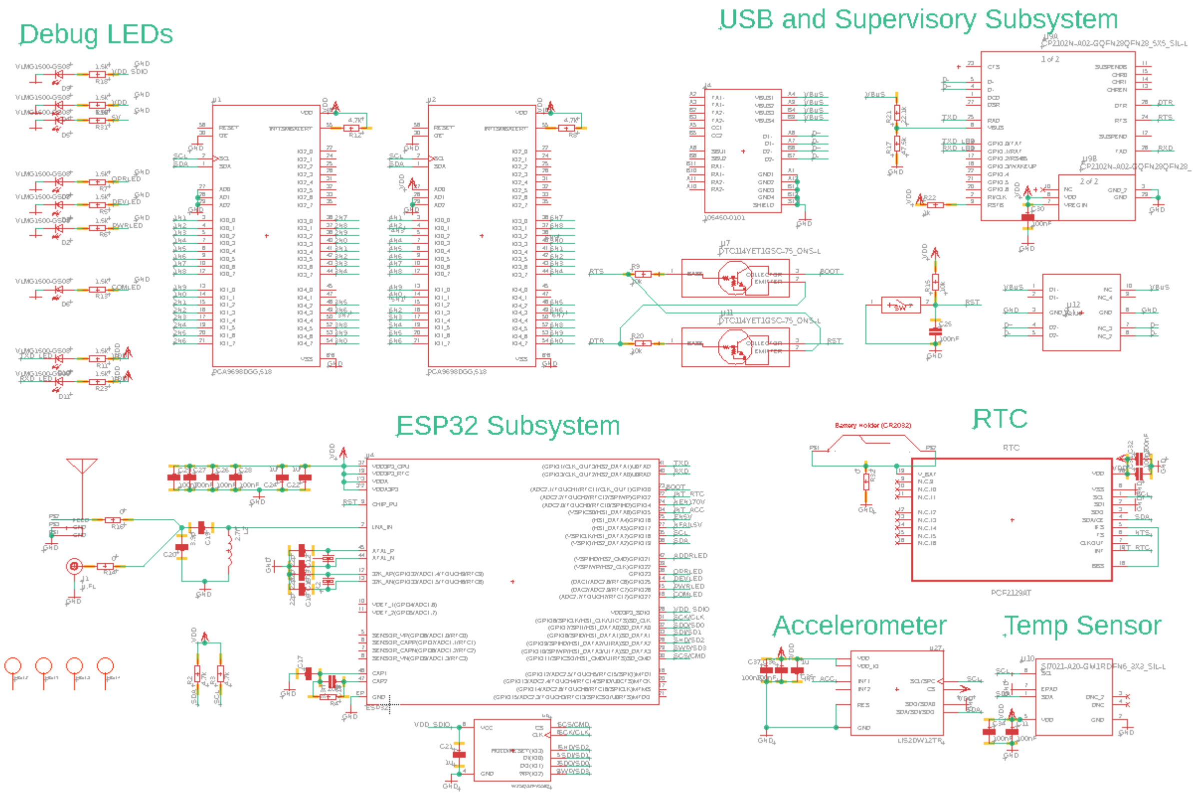


Figure 2: Digital/RF System Circuit Schematics

5.1.2 Power Management System

The power management system supplies the NTC with 3 separate power rails (3V3, 5V, 170V) when powered from DC 12V, or 3V3AUX (connected to 3V3) when powered from USB as shown in Figure 3. The NTC must not be powered simultaneously from DC 12V and USB.

The 3V3 rail is generated by TPS82140(1) which is designed to supply 750mA (or AMS1117-3.3 when connected to USB)

The 5V rail is generated by TPS82140(2) which is designed to supply 1.15A. The 5V rail also has a voltage monitor.

The 170V rail is generated by MAX1771 which is designed to supply 75mA. It can be adjusted between 145V - 190V to fine tune the cold-cathode tube's firing voltage.
The DC 12V input is protected by a polyfuse with It 1.25A 100ms.

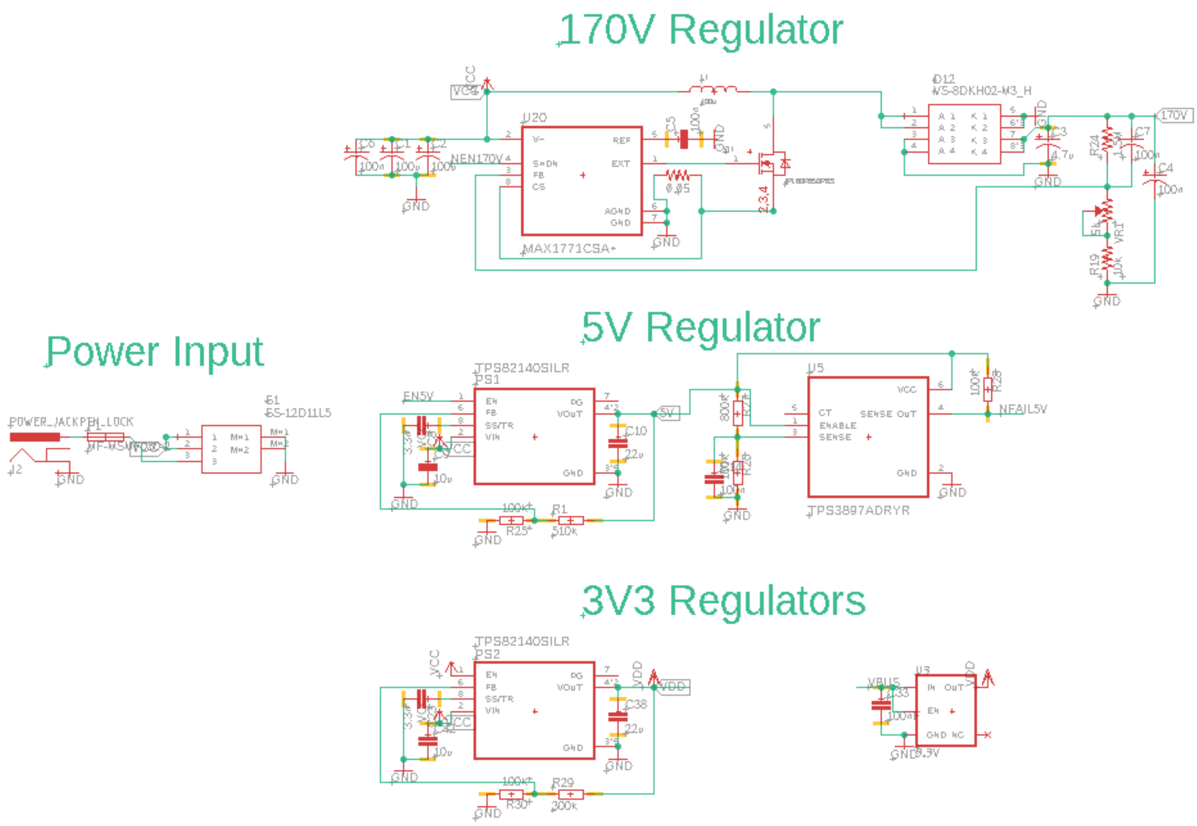


Figure 3: Power Management System Circuit Schematics

5.1.3 Others

The NTC integrates 8 ULN2803 darlington transistor array cathode drivers which are controlled by the 2 GPIO expanders in Section 5.1.1.
The NTC also has 6 ARGB LEDs for illumination of the cold-cathode tubes which are powered from the 5V rail and controlled via a single data line.

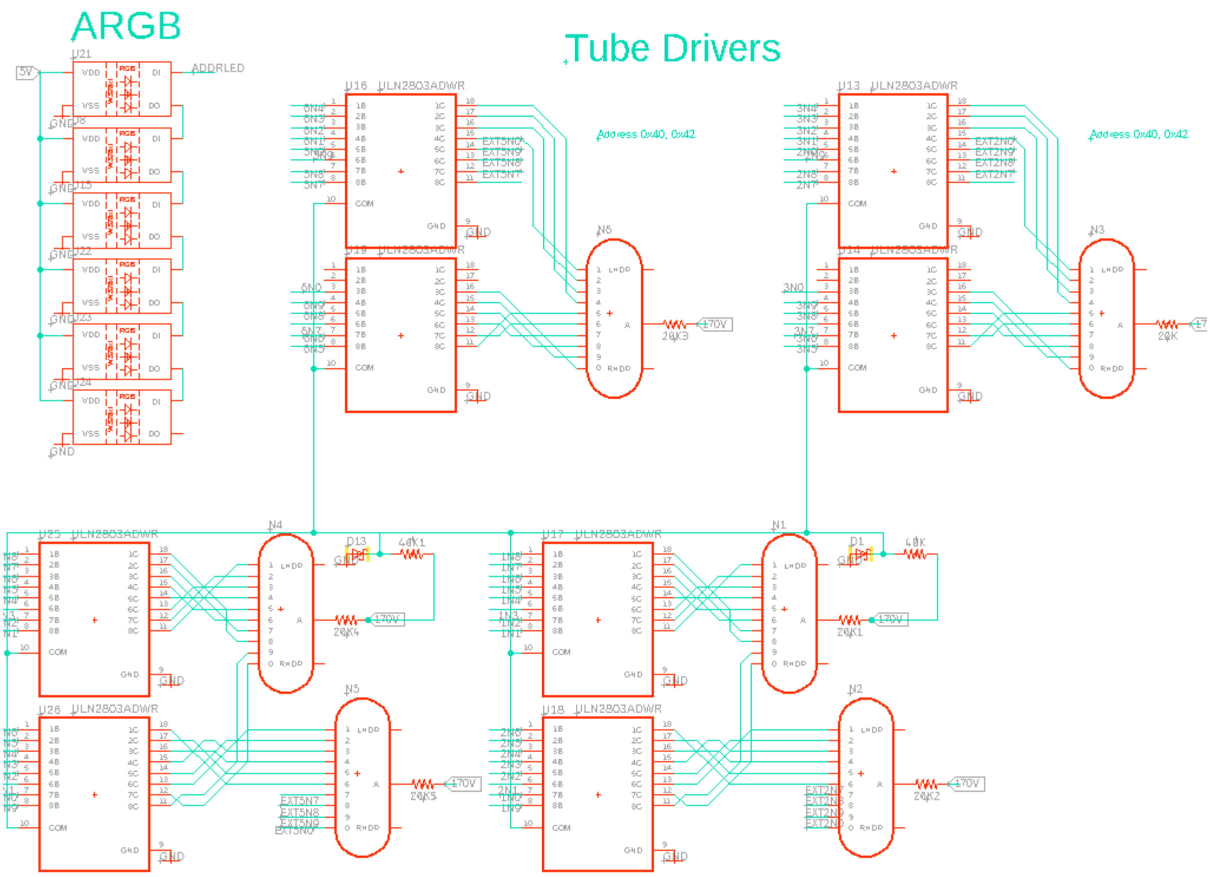


Figure 4: NTC Unclassified Circuit Schematics

5.2 Enclosure and Assembly

The enclosure (see Section 7) is made from nylon-12 material and is not designed to be subject to drops, high temperatures above those specified in Section 5.3 and corrosive compounds.

All necessary connections and indicators are found at the rear of the NTC as shown in Figure 5 below.
From left:
the USB Port is used for programming and debugging the NTC as mentioned in Section 5.3;
the Indicator LEDs are used for software debugging;
the 12V Supply Input is the input connector for the power supply;
and the Power Switch is used to turn the NTC on or off.

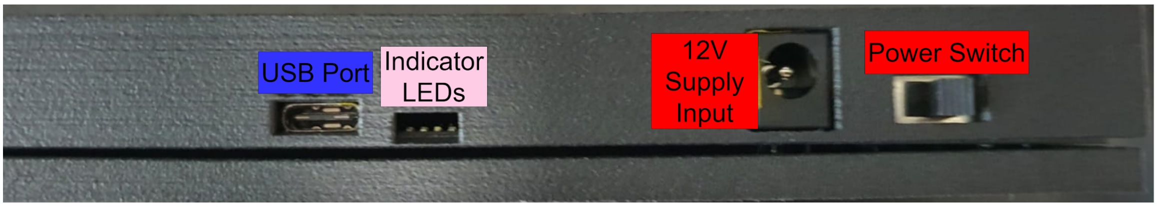


Figure 5: NTC Rear IO Ports

5.3 Programming and Debugging

The NTC USB port allows for configuration of USB parameters and behavior, and direct programming of the onboard ESP32 SoC. The ESP32 is programmable via esptool serial bootloader utility, while the USB settings are modifiable in Silicon Labs Simplicity Studio under device-type “CP2102N-AQFN28”.

6 User Information

6.1 First Power-on and Safety Information

Before the NTC is powered on, ensure all protective covers and tape are removed, and the USB port is disconnected.
Insert the power supply power jack into the 12V Supply Input in Figure 5 and turn on the device.

Safety notice
Do not obstruct, insert any objects into, or otherwise impede with the proper functioning of the thermal exhaust vent. Inserting conductive material into the vent also poses a risk of electrical shock. Do not expose the NTC to excessive moisture, heat or light.

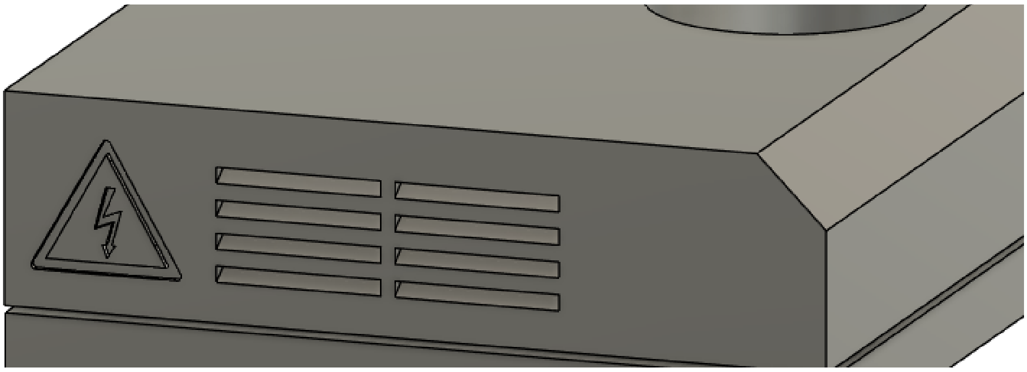
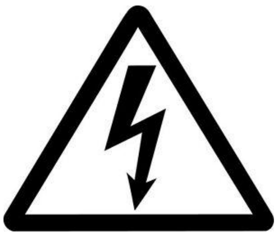
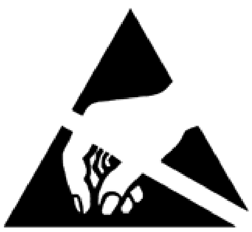


Figure 6: NTC Thermal Exhaust Vent

The NTC contains high DC voltages; there is a risk of electric shock. Only qualified personnel with suitable equipment should attempt disassembly or repair. Capacitors may remain charged even after the power supply is removed.



ESD notice
This device is sensitive to ESD shocks and must not be subjected to ESD outside of the stated rating in Section 4.1.



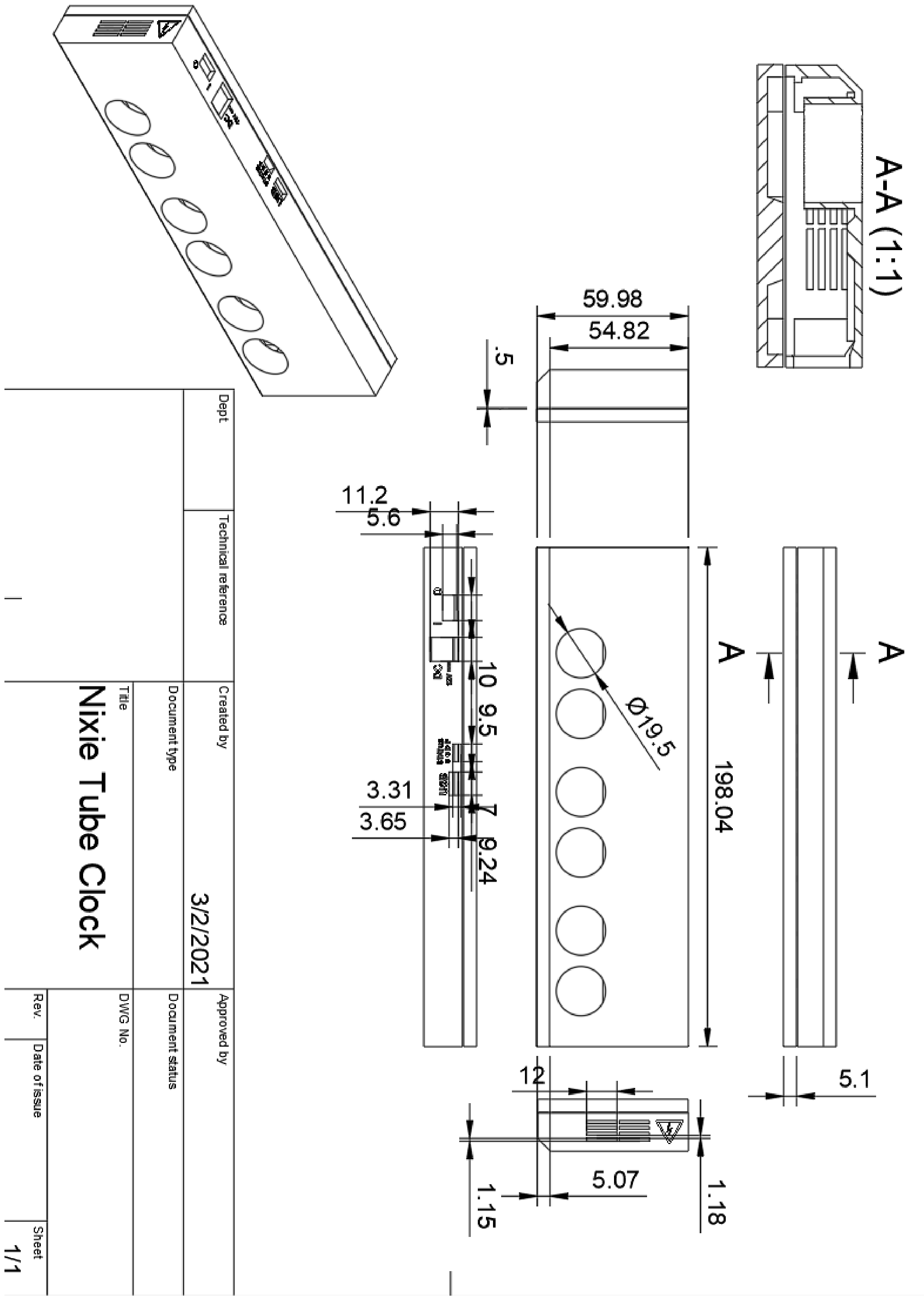
6.2 Troubleshooting

This Section lists common problems and the respective resolutions faced when using the NTC.

Issue	Likely Cause	Resolution
NTC does not power on	DC power jack incorrectly seated	Reseat power jack
	Invalid power supply	Replace power supply and ensure it is rated at 12V and delivers more than 1A
Wireless range is worse than expected	RF obstruction in near-field	Ensure no metal objects in close proximity to NTC
NTC USB not detected	No drivers	Install CP2012N drivers
	Incorrect or faulty USB cable	Replace USB cable and ensure that cable is not confused with a thunderbolt cable with USB-C type plug
Tube does not light	Firing voltage of tube increased	Adjust voltage regulator
Multiple digits light up simultaneously	Internal short in tube	Shake tube or replace

Table 2: Common problems

7 Mechanical Drawings



8 Design Errata and Known Limitations

b	Issue	Conditions	Consequences	Workaround	Status
1	Nixie tube footprints reversed	Always	Tubes face backwards	Apply errata[1] workaround used to counter reverse nixie tube footprints	Workaround applied
2	Active low OE PCA9698 pins unconnected	Always	Tubes brightness is not controllable	PWM NEN170V TBC	Not implemented
3	LIS2DH12TR depreciated	N.A.	Accelerometer module is unusable	N.A.	Not used
4	Input capacitor C1 obstructs enclosure	Always	PCB does not fit in the enclosure	Remove C1 and increase value of C2	Workaround applied
5	RTC gnd pad unexposed	Always	RTC battery disconnected from VBAT	Remove solder mask portion below battery	Workaround applied
6	PCA9698 pull-up incorrectly connected to INT instead of RST	Always	PCA9698 always held in reset	Bridge pull-up and bridge PCA9698 INT and RST	Workaround applied

Table 3: Design Errata and Known Limitations

9 Ordering Information

9.1 Enclosure Labels

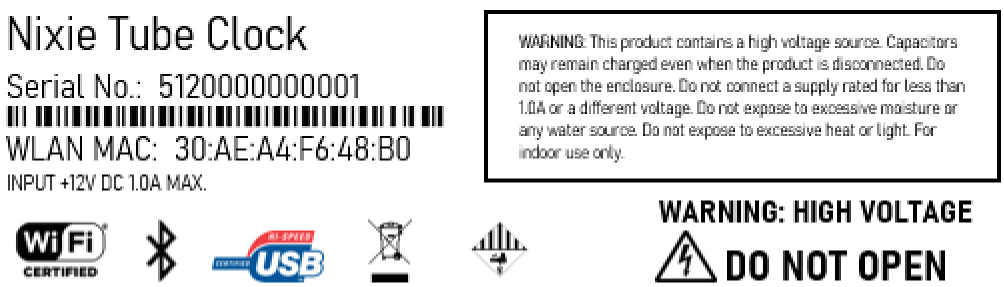


Figure 6: Enclosure product information label (bottom)

9.2 Order Code

The NTC order code (“Serial Number”) follows this format:

512 <V> <XXXXXXXXX>

Abbreviation	Definition and Implemented Codes
512	NTC Product Internal Identifier
<v>	Hardware version code E - Engineering version 0 - Production rev0 1 - Production rev1
<XXXXXXXXX>	9 digit unique device identifier

Table 4: Ordering Code Definitions