NMEATrax - Final Report

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December 11, 2022

Submitted to:

Kimberly Lemieux

For ENGL 273 & Capstone

Memorandum

To: Kimberly Lemieux

From: Alex Klouda, Greyson Stelmaschuk

Date: December 11th, 2022

Re: Marine Data Tracking Device

Hi Kimberly, we hope you are well; the NMEATrax group is happy to again report that we have made excellent progress on our project. We have completed our symposium-ready prototype on schedule.

Our device has met our design goals and is ready for use onboard a marine vessel. Our device successfully reads and parses NMEA 0183 and NMEA 2000 data, displays this information wirelessly on our web interface, stores historical trip data with the ability for it to be replayed, and was created using cost-efficient design solutions.

Additional time has been spent polishing our device, improving stability, creating an interactive element for our display, testing, and improving the aesthetics of our device.

The opportunity to create a market-ready product of our own design is a unique and valuable experience; we appreciate Camosun College for providing us with a chance to create a device that we are proud of. We would also like to thank the Camosun community for the support they have provided during the development of this project.

Thank You,

NMEATrax

Executive Summary

Purpose-built for personal and commercial marine vessels, NMEATrax provides a low-cost alternative to traditional single-function marine data displays while including additional features beneficial to both commercial and leisure vessels.

Compatible with both the NMEA0183 and NMEA2000 standards, NMEATrax allows users to access vessel information through internationally recognized NMEA networks. Users can access a compressive display by simply plugging our device into their existing network. Powered by an ESP32 system on a chip, our device creates a mobile WiFi access point, allowing users to view data through intuitive real-time interfaces on our web portal.

NMEATrax differs from other monitoring systems by creating a log of data on an SD card and using mobile devices as displays. Our desktop application allows users to view recorded data for analytics, diagnostics, and performance monitoring. Additionally, our mobile display feature significantly lowers the cost of our product while also providing users with a high-definition screen and ability to connect multiple users simultaneously.

Background

Communication standards define the common rules used by networked electronics to communicate with each other without compatibility issues. Despite many different proprietary standards, NMEA protocols have gained widespread adoption onboard both commercial vessels and pleasure crafts.

However, full access to marine data is not universally available on vessels and can be prohibitively expensive. As a result, many boaters cannot access the information created by the electronics they have purchased.

Design

NMEATrax has developed a successful and effective marine monitoring system with several unique features and benefits. Our device can read, display, and log accurate information from networked marine devices in real-time, providing users with valuable information about their vessel. Outfitted with an SD card, information can

be recorded, downloaded and replayed on demand. The web interface and desktop app are both user-friendly and intuitive, making it easy for users to access and interpret the data.

Results

NMEATrax has developed a successful and effective marine monitoring system with several unique features and benefits. Our device can read, display, and log accurate information from networked marine devices in real-time, providing users with valuable information about their vessel. The web interface and desktop app are both user-friendly and intuitive, making it easy for users to access and interpret the data. Additionally, the device is plug-and-play, requiring no user interaction to begin operation.

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Introduction

Marine electronic networks are necessary for the safety, efficiency, and effectiveness of ships and boats [1]. However, full access to marine data is not universally available to all vessels and can be prohibitively expensive. Many boaters are unable to access all the information created by the electronics that they have purchased.

NMEATrax is a device that allows low-cost access to the information related to the operation and position of any vessel. Design choices, such as utilizing mobile devices already owned by users as a high-definition display, have been incorporated as a new, low-cost way to display marine information. Our device is self-contained, requiring no external services while offering features not found in other information displays, like our voyage replay feature.

Background

Despite its centuries long history, boating has and continues to become increasingly modern. Our group understands the importance of looking into the background of both historical and modern technologies and communication standards to create a superior device that addresses the needs of boaters.

Communication

Languages are the primary form of human communication; people create languages when they accept a common meaning to symbols, conventions, and syntax. Like humans, electronics require a commonality to speak amongst each other in a meaningful way. Communication standards define the common rules used by networked electronics to communicate with each other without compatibility issues.

Marine Networking

The internals of modern vessels now more closely resemble a server room than an 18th-century sailboat. Many modern boats contain a complex network of instruments, sensors, and displays. These networks have become an essential tool for mariners, allowing them to navigate waters efficiently.

With the growing prevalence of networked devices, many competing standards have arisen. Therefore, it's necessary to select a single communication standard between these devices.

The National Marine Electronics Association (NMEA) is one such standard organization [2]. They have created the NMEA 0183 and NMEA 2000 communication standards, both of which have been adopted globally.

Compatibility

Despite many other proprietary standards, NMEA protocols have become fixtures onboard vessels, with uses ranging from industrial marine to pleasure craft operation. Popular manufacturers, including Garmin and Honda, produce NMEA 2000 certified devices [3] [4]. Alternative standards exist using similar topology; however, they are proprietary and use brand-specific connectors [5]. The similarity in topography and data format means that NMEATrax can be easily adapted to parse the information on these networks by simply using an adaptor cable.

Opportunity

There is a void in the market for captains and boaters who require a small, low-cost, portable device, with features that log necessary marine information. Similar marine monitoring systems are expensive, proprietary, do not log information, and require a constant connection to a computer. To remedy this, we have created a low-cost, open-source device that requires no interaction with external tools.

With a total prototype component cost of $41.89, NMEATrax is many times cheaper than alternatives; a cost breakdown of individual component costs is available in Appendix D. Additionally, NMEATrax does not require expensive peripherals like an

additional computers or single purpose display, further reducing implementation costs.

Onboard pleasure crafts, NMEATrax can replace traditional displays, allowing users to monitor data for performance insight and diagnose issues. In a commercial setting, NMEATrax's voyage replay app allows for the monitoring of fleets and gives users the ability to monitor analytics to save costs. Additionally, our device has uses in vessel service and repair. Our device is portable, features a small form factor, and is able to be connected to existing networks without disruption. Technicians can carry NMEATrax between jobs, giving them access to a portable display on any vessel they are servicing.

Approach

As a group, we have elected to approach our project collaboratively with decisions made through discussion. To design our project, our team began by identifying several key goals that we considered essential to our device:

1. Accurately read boat sensor data from a NMEA network.
2. Display this information clearly and wirelessly on a web interface.
3. Store historical trip data to allow users to replay previous trips.
4. Use cost-effective solutions to solve design challenges.

Our group delegated these goals between group members through discussion, with mutual agreement required. Factors that were considered for assigning tasks included each individual's skill set, the length of time each task will take to complete, and each group member's enthusiasm for the task.

This method has allowed us to create an organized, scope-focused approach while designing our device. As a result, we have managed to produce a fully functional and cohesive product.

Hardware Design

To create a device suitable for a competitive market, NMEATrax has carefully considered each design choice to maximize the cost-effectiveness of our product.

As a result, we have selected an ESP32-based design. The ESP32 is one of the highest cost to performance System On Chips (SOCs) available [6]. In addition, the line of SOCs available from Espressif are simple to program, with vast availability of libraries, making them the optimal choice for this project.

PCB

To reduce consumer expense while meeting the goals outlined for this product, we created a custom 4-layer PCB; Figure 1. shows a 3D-rendering of our completed PCB design. Our designed ensured that we could include all the components required for a successful product in as small of a package as possible. We accomplished this by using small, 0603-sized resistors and capacitors where possible. This allowed the PCB size to be just 45mm by 75mm. Schematic diagrams are available in Appendix B. and the layout of our PCB in Appendix C.

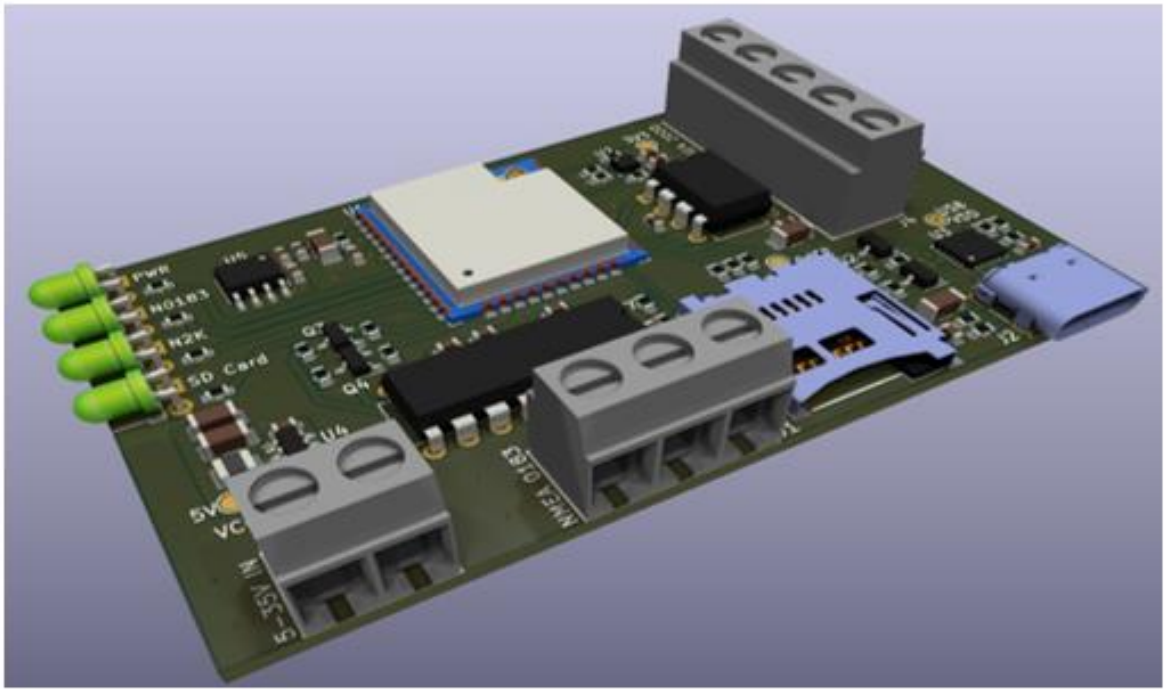

Figure 1. A 3D rendering of our custom made PCD.

Enclosure

Due to confined installation areas, we determined that a small form factor enclosure is essential for this product. From inception, we considered this and have created an enclosure with a footprint of 140mm by 70mm, compact enough to be sheltered in even the smallest marine electronics cabinets. In line with our low-cost design philosophy, the protection provided by the electronics cabinet allows our device to avoid the harsh ocean environment, forgoing the need for an expensive, corrosion-proof, and waterproof design. Figure 2. depicts a rendering of our enclosure design.

Figure 2. A 3D model of our enclosure.

Firmware Design

Our device, driven by an ESP32 SOC, provides the firmware necessary for us to easily interface with the low-level data in our system.

Data

Due to the vast amount of information flowing through a NMEA network, displaying all information simultaneously would lead to a convoluted and confusing user experience. We have identified the most relevant information to our users' needs through real-world testing. Appendix A. shows the marine network data our group has selected to be read and processed.

NMEA 2000

The highest priority for this project is the ability to decode and display NMEA 2000 data from a vessel's network. Figure 3. shows a small portion of NMEA 2000 data captured by our device from a real vessel.

NMEATrax achieved this by using an extensive NMEA 2000 library developed by Timo Lappalainen and Kave Oy. This library is licensed under the MIT license, providing free use. The NMEA 2000 library manages the parsing of incoming data [7]. Our code then takes the decoded vessel data and sends it to the web server and SD card.

```
In Main Handler: 127488
Engine rapid params: 0
  RPM: 618.00
  boost pressure (Pa): not available
  tilt trim: 0
In Main Handler: 127493
Transmission params: 0
  gear: forward
  oil pressure (Pa): not available
  oil temperature (C): not available
  discrete status: 0
```

Figure 3. A text file containing parsed and decoded NMEA 2000 information.

NMEA 0183

Our device is also able to decode and process certain NMEA 0183 sentences. Easy to use, adaptable, and available for free use under GNU licensing, the Tiny GPS Plus library created by Mikal Hart is an excellent fit for our project [8]. This library provides Espressif devices an interface to easily parse and decode any data on NMEA 0183 networks.

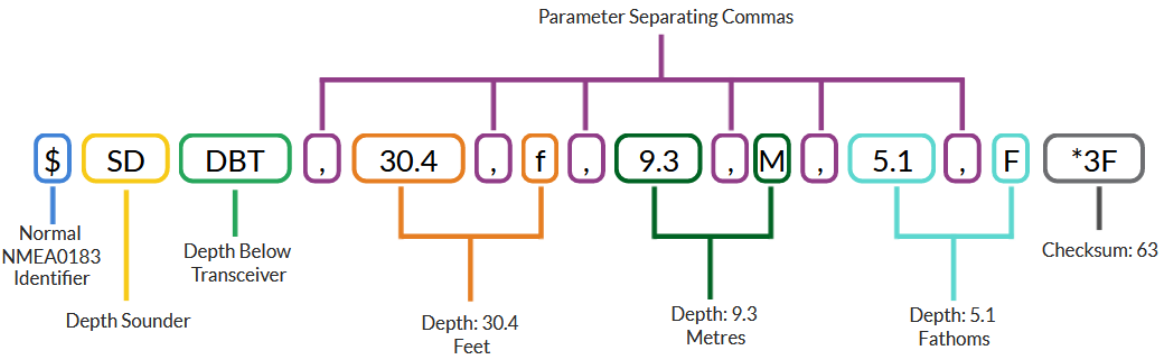

Figure 4. A parsed NMEA 0183 sentence with a brief description of each parameter.

NMEA 0183 data is encoded as simple-to-understand ASCII characters, arranged into NMEA 0183 sentences. Figure 5. demonstrates how NMEA 0183 sentences displayed in ASCII can be simply understood without the use of a computer [9]. The ESP32 incorporated in our device can quickly extrapolate information from this format, translating obfuscated strings into digestible information.

Web Server

To view our data, we have created a web browser-based monitoring interface that can display the data as gauges or as text, with the latter designed and tailored to the specific needs of mobile users. Our web interface also provides users with access to a settings page, allowing for modification of the local WiFi SSID and password, recording intervals, units, and more. Figure 6. depicts the gauge view of the web interface.

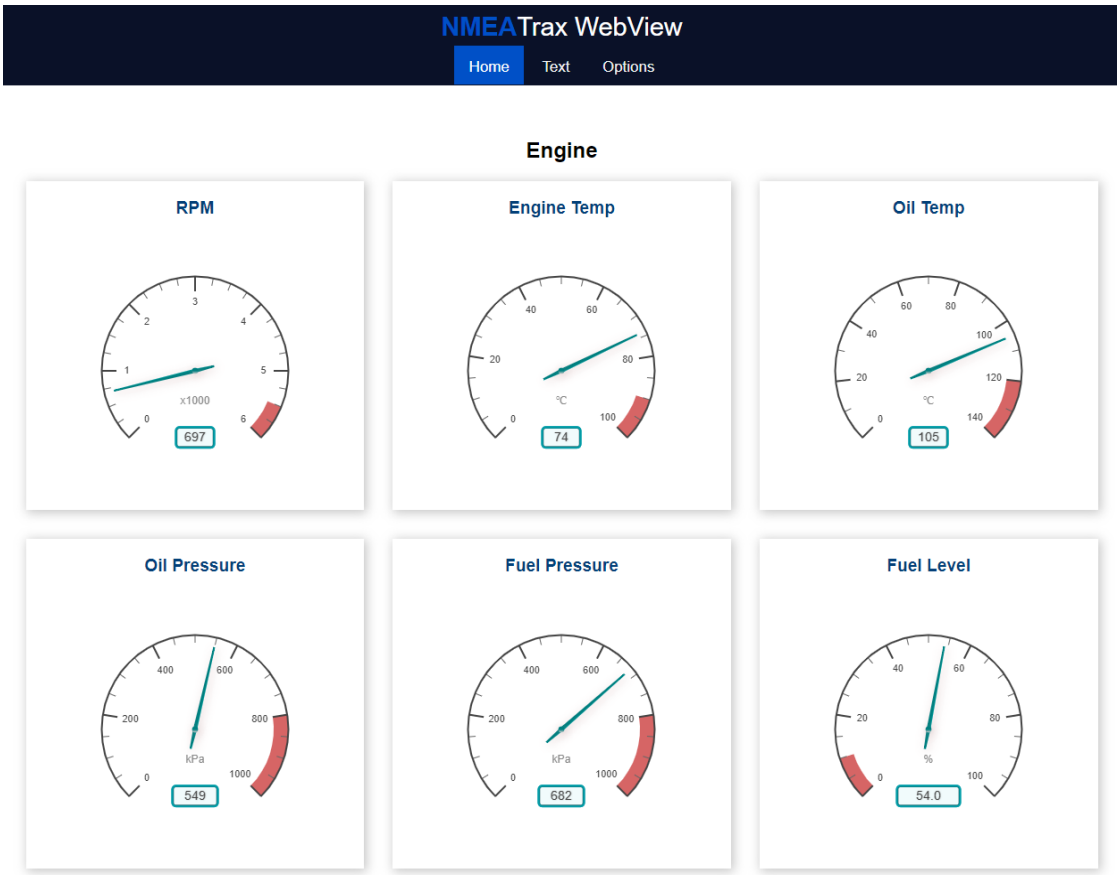

Figure 5. An image of NMEATrax WebView's gauge-based information display.

The web server sends a JavaScrip Object Notation (JSON) string containing all of the NMEA data to the client device every second. The JavaScript embedded on the web page then breaks the JSON string into individual variables used to display the data. Finally, the user can choose for NMEATrax to connect to an existing wireless network or broadcast its own.

SD Card

While on the water, NMEATrax records parsed marine network data to an SD card. To give users control over how fast onboard memory is expended, they can control how often they save data by modifying the “Recording Interval” setting on the web interface. The data is stored as a Comma-Separated Values (CSV) file, which contains every parsed value displayed on the web interface when writing. This file is available for download via the web interface or directly off the SD card for replay on our desktop app.

Software

NMEATrax, as a system, includes decoding information, hosting a wireless access point with a web interface, and a desktop application. To achieve this efficiently, we have utilized several different coding languages. We chose to create our decoding software in C++ due to the availability of libraries and the ease of interfacing with our onboard ESP32. To create a lightweight, functional, and intuitive interface for our device’s web interface HTML, CSS, and JavaScript were used. Additionally, our desktop application was created using C# due to quick development time, combined with ease of use.

Replay App

A unique feature of NMEATrax is its companion desktop application. Any information our device logs to our SD card can be reviewed through the desktop application. Shown in Figure 7. is the Replay App. This app allows the user to review the information as it was recorded and analyze the data. When reviewing the data,

any value that exceeds the limits specified will be highlighted in red. This can be useful when the user is not expecting any parameter to be problematic. The analyze feature looks through the entire recorded file and searches for instances where the selected parameter exceeds the limits specified. The offending moments will be listed in the output box.

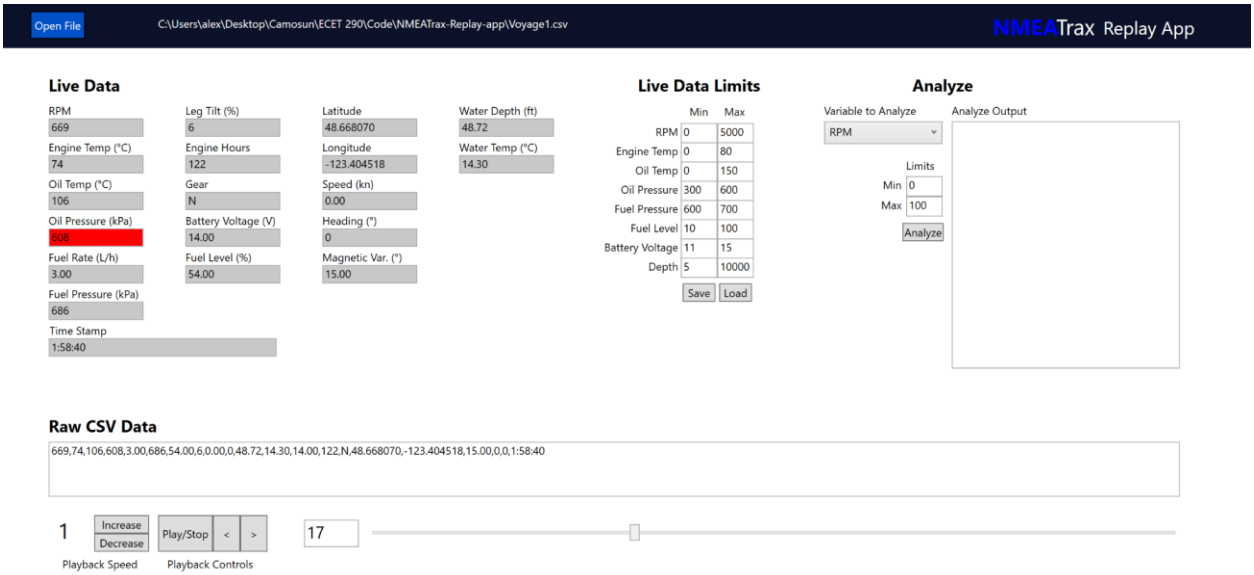

Figure 6. NMEATrax's replay app.

Recommendations

Plans for the second version of NMEATrax are already in place. To further reduce the form factor and create a more robust device, the second version of NMEATrax will see the screw terminal used to interface with a Micro-c NMEA 2000 connector replaced with a whole through PCB-mounted right-angled Micro-c connector.

Conclusion

NMEATrax has designed an effective marine monitoring system unique from commercially available alternatives. Our prototype is vessel ready and is proof that it is possible to display vessel information at a low cost without compromising an intuitive and modern format.

We adhered to our design principles while completing our goals as a group. We designed a circuit that accomplishes our device's needs while using inexpensive, easily sourced components. We have created an enclosure that complements our device; our custom-designed 3D-printed enclosure offers our device impact protection and multiple mounting options. Both ways for users to interface with our device, the web interface, and the NMEATrax desktop app are fully functional, informative, and intuitive. We have created our product with the limited space of the average marine electronics cabinets in mind.

Through this design, our device has some tangible results. Our WiFi access point reached shipwide coverage onboard a vessel. Additionally, our device reads, displays, and logs accurate information generated by networked marine devices in real time. NMEATrax is a plug-and-play device; when connected to an existing NMEA network, our device begins to operate immediately without user interaction.

NMEATrax is a fully functional and successful product. Our device would be a great addition to commercial vessels and pleasure crafts alike. Our group is excited to know that version two will become a fixture onboard a vessel seeing real-world use, granting its users a more informed boating experience.

References

[1] K. Englert, "The Basics of NMEA 2000," Boating Mag, 21 November 2014. [Online]. Available: https://www.boatingmag.com/gear/basics-nmea-2000/. [Accessed 30 October 2022].

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[4] "Honda Marine," Honda, 14 12 2022. [Online]. Available: https://marine.honda.ca/. [Accessed 14 12 2022].

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[7] T. Lappalainen and K. Oy, "NMEA2000," 27 October 2022. [Online]. Available: https://github.com/ttlappalainen/NMEA2000. [Accessed 30 October 2022].

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[10] "NMEA 0183 Rx Sentence to NMEA 2000 Tx PGN List," ONWA Marine Electronics, 26 January 2022. [Online]. Available: https://onwamarine.com/nmea-0183-rx-sentence-to-nmea-2000-tx-pgn-list/. [Accessed 30 October 2022].

Appendix A.

Table 1. An overview of decoded networked information [10].

NMEA 2000 PGN	NMEA 0183 Identifier	Name	Description
127250	HDG, HDM, HDT, VHW	Vessel Heading	Direction the vessel is facing
127488	RPM	Engine Parameters, Rapid Update	Frequent updates of RPM and leg tilt
127489	—	Engine Parameters, Dynamic	Oil pressure, oil temp, engine temp, etc.
127493	—	Transmission Params	Forward, Neutral, and Reverse
127505	—	Fluid Level	Fuel level
128267	DBT, DPT	Water Depth	Water depth with optional offset
129025	—	Position, Rapid Update	Frequent update of location
129026	VTG	COG & SOG, Rapid Update	Speed over ground and course over ground
129029	GGA, GLL, RMC, ZDA	GNSS Position Data	Satellite data with position and time
130312	MTW	Temperature	Sea temperature

Appendix B.

The following three figures contain the NMEATrax PCB Schematic.

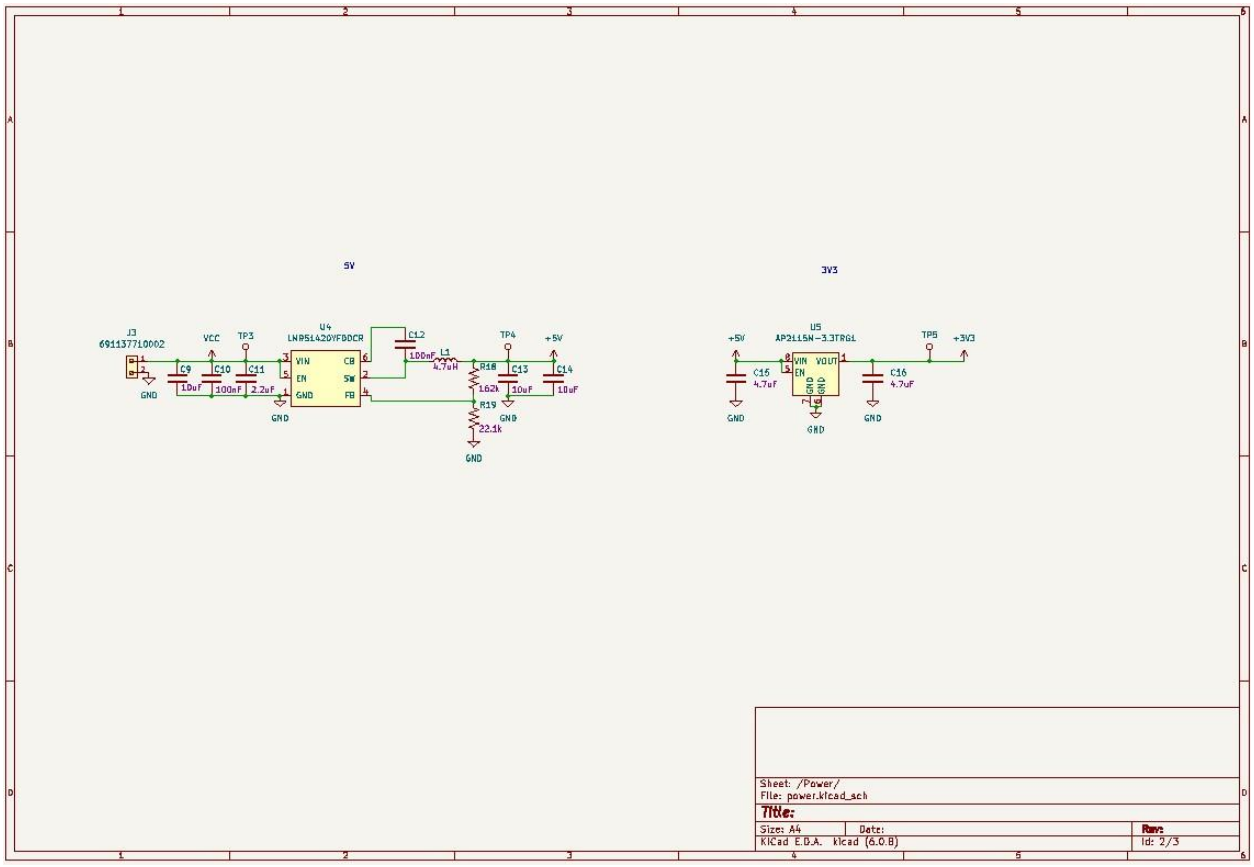

Figure 7. NMEATrax PCB Power Schematic.

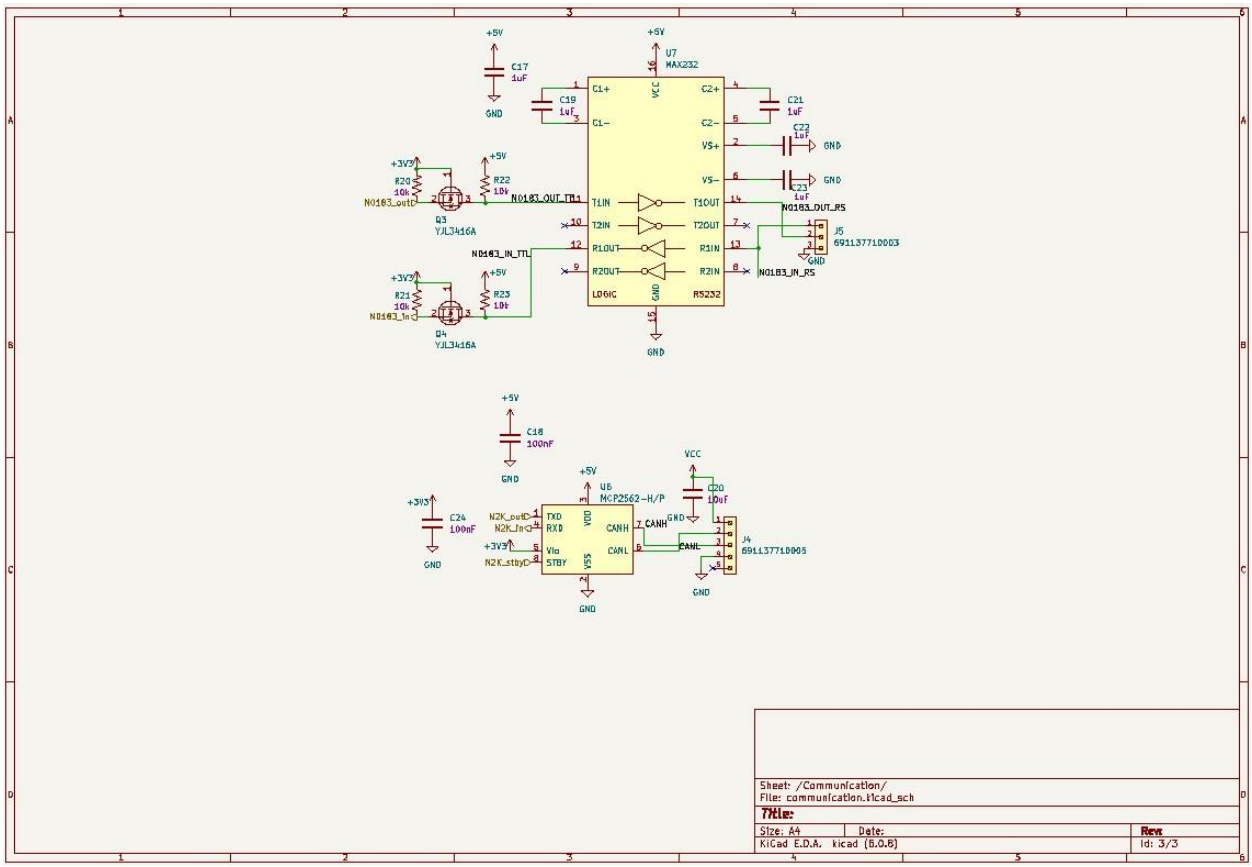

Figure 8. NMEATrax Communication Schematic.

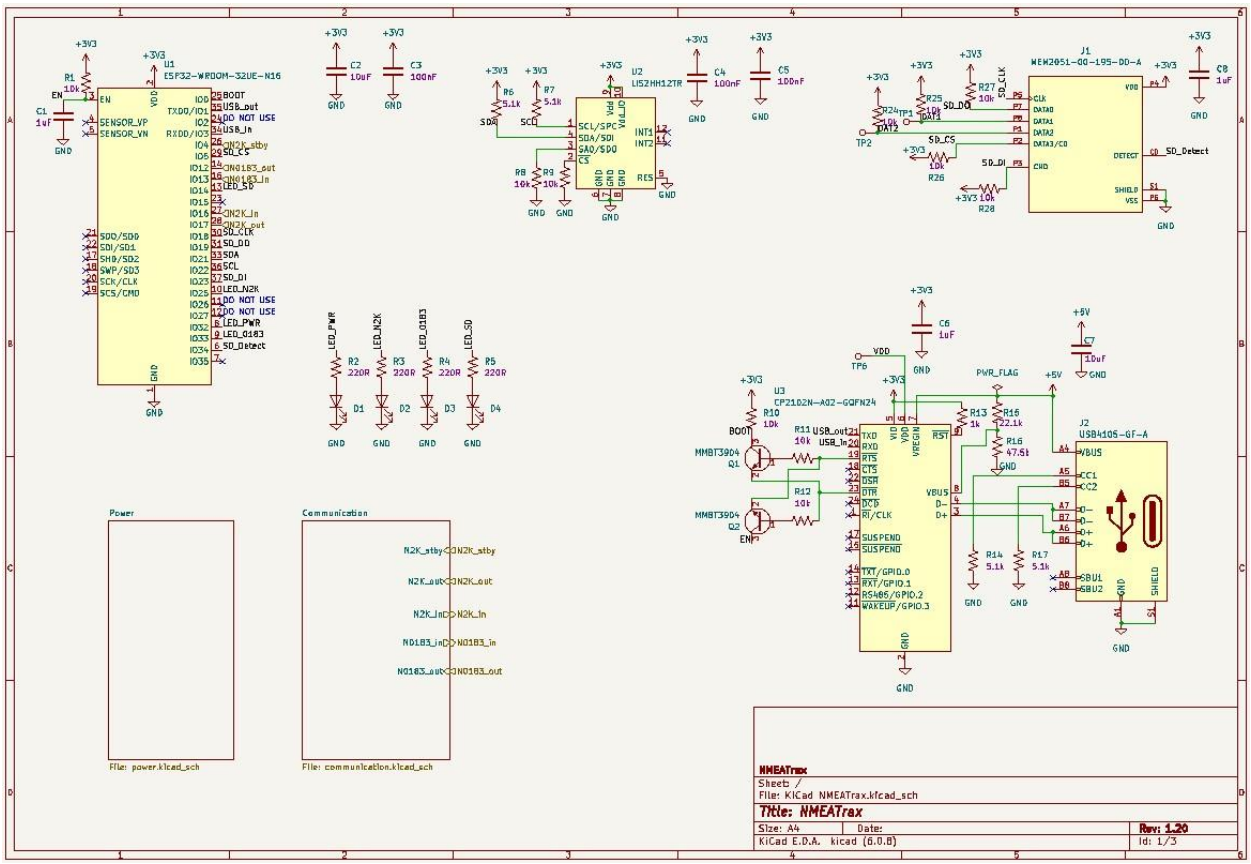

Figure 9. NMEATrax Main PCB Schematic

Appendix C.

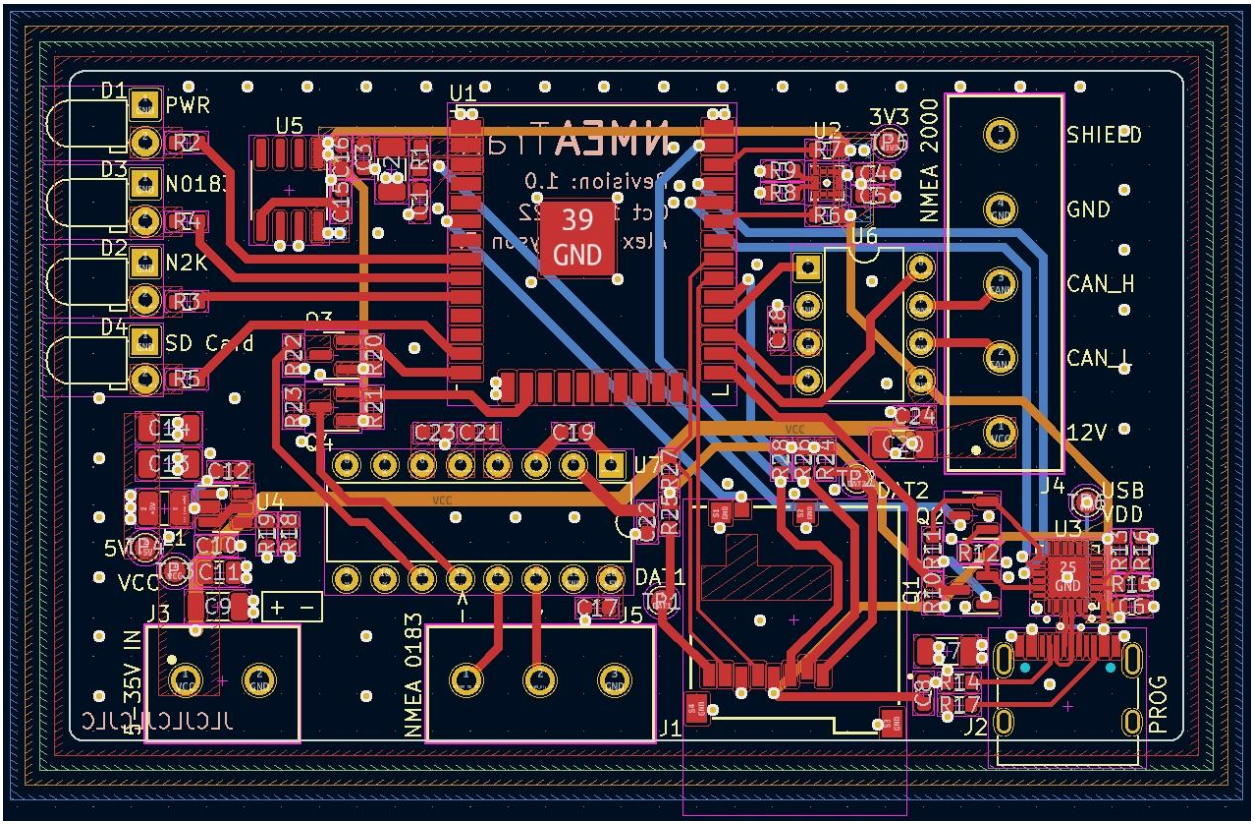

Figure 10. NMEATrax PCB layout.

Appendix D.

Table 2. A cost breakdown of an individual NMEATrax Device.

Qty	Manufacturer Part #	Detailed Part Description	Unit Price ($CDN)	Extended Price
1	ESP32-WROOM-32UE-N16	ESP32-WROOM-32E (8MB) no PCB antenna Bluetooth, WiFi 802.11b/g/n, Bluetooth v4.2 +EDR, Class 1, 2 and 3 Transceiver Module 2.4GHz ~ 2.5GHz Antenna Not Included, U.FL Surface Mount	$5.46	$10.92
1	MEM2051-00-195-00-A	9 (8 + 1) Position Card Connector Secure Digital - microSD™ Surface Mount, Right Angle Gold	$1.71	$3.42
1	LIS2HH12TR	Accelerometer X, Y, Z Axis ±2g, 4g, 8g 5Hz ~ 400Hz 12-LGA (2x2)	$2.84	$5.68
1	MCP2562-H/P	1/1 Transceiver Half CANbus 8-PDIP	$2.17	$4.34
1	USB4105-GF-A	USB-C (USB TYPE-C) USB 2.0 Receptacle Connector 24 (16+8 Dummy) Position Surface Mount, Right Angle; Through Hole	$1.15	$2.30
1	691137710002	2 Position Wire to Board Terminal Block Horizontal with Board 0.197" (5.00mm) Through Hole	$0.41	$0.82
1	691137710003	3 Position Wire to Board Terminal Block Horizontal with Board 0.197" (5.00mm) Through Hole	$0.94	$1.88
10	CL10A105KA8NFNC	1 µF ±10% 25V Ceramic Capacitor X5R 0603 (1608 Metric)	$0.15	$1.84
10	CL10B104KB8WPNC	0.1 µF ±10% 50V Ceramic Capacitor X7R 0603 (1608 Metric)	$0.15	$1.74
10	CL31A106MBHNNNE	10 µF ±20% 50V Ceramic Capacitor X5R 1206 (3216 Metric)	$0.40	$5.54
5	CL10A475KP8NNNC	4.7 µF ±10% 10V Ceramic Capacitor X5R 0603 (1608 Metric)	$0.15	$0.64

Qty	Manufacturer Part #	Detailed Part Description	Unit Price ($CDN)	Extended Price
1	CL21A225KBFNNNE	2.2 µF ±10% 50V Ceramic Capacitor X5R 0805 (2012 Metric)	$0.33	$0.66
5	RMCF0603JG5K10	5.1 kOhms ±5% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thick Film	$0.16	$0.20
5	RMCF0603FT22K1	22.1 kOhms ±1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thick Film	$0.16	$0.24
5	RMCF0603FT1K00	1 kOhms ±1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thick Film	$0.16	$0.24
5	RMCF0603FT47K5	47.5 kOhms ±1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thick Film	$0.16	$0.24
1	ERJ-3EKF1623V	162 kOhms ±1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thick Film	$0.16	$0.76
1	DFE252012P-4R7M=P2	4.7 µH Shielded Drum Core, Wirewound Inductor 2 A 200mOhm Max 1008 (2520 Metric)	$0.49	$0.98
2	BL-BGE1V1	Green 569nm LED Indication - Discrete 2V Radial	$0.49	$1.96
2	BL-BBE3V1	Blue 460nm ~ 475nm LED Indication - Discrete 3.2V Radial	$1.10	$4.40
2	YJL3416A	N-Channel 20 V 7A (Ta) 1.3W (Ta) Surface Mount SOT-23	$0.4300	$1.72
2	MMBT3904_R1_00001	Bipolar (BJT) Transistor NPN 40 V 200 mA 300MHz 225 mW Surface Mount SOT-23	$0.1700	$0.68
1	691137710005	5 Position Wire to Board Terminal Block Horizontal with Board 0.197" (5.00mm) Through Hole	$1.6700	$3.34
1	CP2102N-A02-GQFN24	USB Interface IC USBXpress - USB to UART Bridge QFN24	$2.98	$5.96
1	LMR51420YFDDCR	Switching Voltage Regulators SIMPLE SWITCHER power converter 4.5-V to 36-V, 2-A,	$2.15	$4.30

Qty	Manufacturer Part #	Detailed Part Description	Unit Price ($CDN)	Extended Price
		synchronous buck with 40-uA IQ		
1	PCB	Custom Designed 4 Layer PCB.	$4.10	$4.30
Prototype Cost:				**$41.89**