ME218c Smart Product Design

ME 218c Spring 2018: Edner's Game

Project Preview on May 25 from 1-5 pm. **Grading Session** on May 29 from 1-5 pm.
Project Presentation on May 30 starting at 5:00 pm.

Goal:

The goal of this project is to provide a framework in which you can apply your knowledge of microcontrollers and multi-processor communications to a task that will provide an enjoyable experience for the users and the observers.

Purpose:

The underlying purpose of this project is to provide you with an opportunity to gain experience in integrating all that you have learned in the ME218 course sequence, with an emphasis on the new material in ME218c.

Background:

As with many Olympics, the IOC[1] has decided to demo a new event at this year's games in preparation for next year. Outright conflict between systems has not been seen in the galaxy for some time, and so the IOC has decided to stage a series of war games. Each team consists of several Somewhat Holonomic Immersible Platforms (SHIPs), controlled by Active Navigation, Sensing, and Indication Battle Link Equipment (ANSIBLEs). Each battle will pit two teams against each other, with the team pushing more SHIPs through the enemy's gate declared the victor.

The Task:

Design and build a teleoperated Somewhat Holonomic Immersible Platform (SHIP) and a companion Active Navigation, Sensing, and Indication Battle Link Equipment (ANSIBLE). Teams of SHIPs will face off in Terman Pond outside SPDL. During games, each team of SHIPs, through their ANSIBLEs, will attempt to herd SHIPs into the opposing team's Gate.

Specifications

General:

- ☐ Each team will construct a SHIP and an ANSIBLE.
- ☐ The SHIPs are devices capable of navigating in Terman Pond while herding the other SHIPs into the gates.
- ☐ The ANSIBLEs are remote controllers for the SHIPs, communicating wirelessly.

Basic Game Play:

- ☐ A game round will be a competition between two teams, each with half of the class' SHIPs and ANSIBLEs.
- ☐ The goal of the game is to score the maximum number of SHIPs through the opposing team's gate.
- ☐ The game ends when a majority of SHIPs on the Battle Pond are in one team's Gate, or when people get bored.

The Battle Pond:

- ☐ The Battle Pond is comprised of a region of Terman Pond, measuring approximately 60 ft by 25 ft (see Figure 1).
- ☐ The boundaries of the Battle Pond are formed by the walls of Terman Pond on the sides, with the ends composed by constructed walls containing the gates at the center.
- ☐ At the beginning of each game the participating SHIPs will be placed in front of their respective gates as shown in Figure 1.
- ☐ Each of the long edges of the Battle Pond will have a refueling station located halfway between the gates.

[1] Intragalactic Olympic Committee

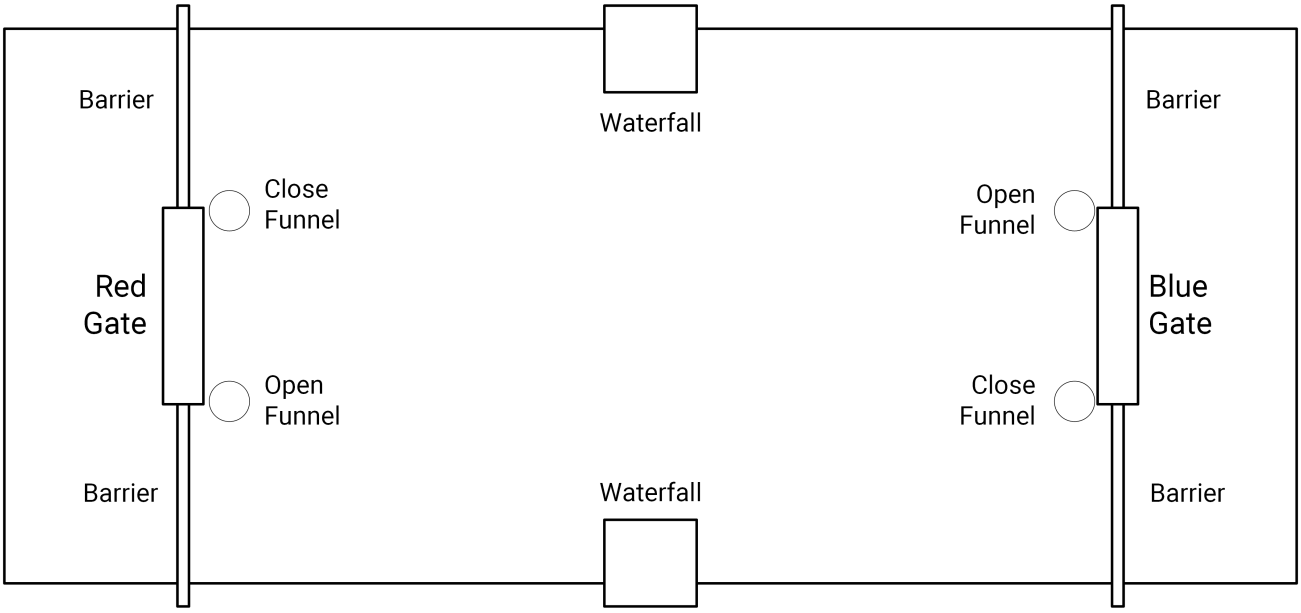

Figure 1: The Battle Pond

The SHIPs:

- ☐ Each SHIP must be capable of moving under its own power within the Battle Pond.
- ☐ SHIPs must be battery powered and operate without a tether. NiCd or NiMH batteries are the only approved power sources.
- ☐ Propulsion and steering systems are not restricted.
- ☐ Control of SHIP functions must be achieved via an ANSIBLE using the provided RF hardware (XBee24 modules)
- ☐ Each SHIP must carry a means of indicating (to the SHIP software) which team it is representing.
- ☐ The SHIP must proudly display their team number.
- ☐ The SHIP must carry a display of the SHIP's home team. This display will be static for each game.
- ☐ The SHIP must carry a display indicating whether the craft is fueled or not fueled.
- ☐ The SHIP must carry a display indicating the current controlling team. The current controlling team will be one of RED, BLUE, or NONE.
- ☐ All displays defined in the above specifications must be interpretable in direct sunlight at a distance of no less than 30 ft in all directions.
- ☐ SHIPs may only expel water above the waterline under pressure provided by a class-standard water pump provided by SPDL.
- ☐ SHIPs must each carry a class-standard Fuel Tank (funnel assembly). Further details are in The Fuel Tank.
- ☐ SHIPs must incorporate an easily accessible switch that disables all moving systems.
- ☐ The perimeter of the largest normal projection of the SHIP to MBPL[2] must not exceed 72". The entire vehicle, projected vertically onto the Pond, must lie within the perimeter, with one exception listed below. Height is not restricted.
- ☐ SHIPs must incorporate a class standard foam bumper around their perimeter, and must be tolerant of

[2]Mean Battle Pond Level

moderate bumping from other SHIPs. The bottom edge of the foam bumper must be at a height between 0" and 1.25" above waterline. The bumper must follow the same perimeter that is measured to fit the 72" requirement.

- ☐ SHIPs may also carry a battering ram/lance made from a 3 ft length of the same class-standard foam material. This battering ram is the only device that may extend beyond the perimeter of the craft.
- ☐ If your team chooses to do so, the battering ram may contain a flexible hose,[3] as long as the hose is fully contained within the battering ram.
- ☐ Every SHIP must be controllable through any of the ANSIBLEs via the class-wide protocol (See Communications).
- ☐ The SHIP may issue messages to the ANSIBLE at a rate no greater than 5 Hz.
- ☐ If the SHIP fails to receive a message from its controller for 1 second, it will assume that there is a problem and revert to the controller search process described under Game Details.

The ANSIBLEs:

- ☐ Each team will design and construct an ANSIBLE that will relay commands from a human operator to a SHIP, and receive and display connection status with the SHIP and fuel status from the SHIP.
- ☐ The ANSIBLE must be capable of displaying to the operator an indication of active communication with its associated SHIP.
- ☐ The ANSIBLE must provide a method for the operator to use between games to change the home team allegiance of the ANSIBLE from BLUE to RED.
- ☐ The ANSIBLE must provide a method for the operator to use to indicate which SHIP (by team number) the operator would like to control.
- ☐ ANSIBLEs must be battery powered, and shall have sufficient battery capacity for at least 8 hours of continuous operation. The report shall show documentation and calculations to support meeting this requirement.
- ☐ ANSIBLEs must be untethered and portable by one person.
- ☐ Input to the ANSIBLE should involve at least 3 sensing modalities (e.g. position, force, audio, acceleration, etc.). Use of unusual interface methods is encouraged.
- ☐ The actions required by the user of the ANSIBLE to issue commands to the SHIP should be inventive and interesting for the audience to watch.
- ☐ The ANSIBLE may issue commands to a SHIP at a rate no greater than 5 Hz.
- ☐ ANSIBLEs should be intuitive to operate, and/or have sufficient visual instructions that a typical spectator (even a non-engineer) would be able to learn its controls within a minute or so. IKEA[4] format instructions are preferred.
- ☐ ANSIBLEs must have a switch that controls their self-identified home team: RED or BLUE.

The Fuel Tank:

- ☐ Each SHIP must have a Fuel Tank.
- ☐ The Fuel Tank will consist of a funnel mounted on a spring and sensing circuitry that can report to the SHIP the current fuel status.
- ☐ The Fuel Tank must be mounted vertically, with the top of the funnel 15 inches above waterline.
- ☐ The funnel must be carried such that it can deflect from vertical by a minimum of 45° in all directions. Furthermore, the funnel must be carried such that it may tip sufficiently far to completely empty the funnel

[3] For example, Tygon®B-44-3 or similar soft tubing. The tubing should not significantly increase the stiffness of the battering ram.
[4] Intragalactic Knowledge Enforcement Agency

in directions away from the SHIP centroid.[5]

- ☐ The funnel must not be protected by a structure on the SHIP that completely prevents it from being contacted by another SHIP's battering ram.
- ☐ Each Fuel Tank will slowly drain of water, eventually causing the SHIP to run out of fuel unless it is replenished.
- ☐ The Fuel Tank will provide a male 4-pin Molex KK254 connector that carries power, ground, and two data lines for asynchronous serial communication.
- ☐ The protocol for communicating with the Fuel Tank is defined in Appendix A.
- ☐ Communication with the Fuel Tank must be accomplished via a PIC12F752 programmed in assembly.

The Gates:

- ☐ The Gates are openings in the end walls 4 ft wide.
- ☐ Access through the Gate is controlled by a sliding door.
- ☐ SHIPs may only pass through the Gate when the sliding door is open; they may not pass over or under the walls or the sliding door.
- ☐ Each Gate has two funnels, located to either side of the Gate. The velocity of the sliding door is controlled by the difference in water level between the two funnels.
- ☐ The funnels, like those on the SHIPs, will slowly drain, and may be tipped by SHIPs.
- ☐ Each Gate will have a display of the speed and direction of the sliding door's movement.

Game Details:

- ☐ Upon power-up, voluntary un-pairing, or in the event of a loss of communication with its current ANSIBLE, the SHIP will activate its display that it has no current ANSIBLE and wait for a request for pairing from an eligible ANSIBLE.
- ☐ ANSIBLE eligibility: any ANSIBLE from any team, except for the ANSIBLE that was most recently paired with a given SHIP, may pair with any un-paired un-fueled SHIP. Fueled SHIPs will only pair with an ANSIBLE from their home team.
- ☐ The operator of an ANSIBLE that wishes to control a particular SHIP must select that SHIP (by SHIP number) using the ANSIBLE, and make a unique control action to initiate taking control of the SHIP. This action will result in the ANSIBLE sending a message to the SHIP requesting control of the SHIP. The details of the request process will be defined in the class-wide communications protocol.
- ☐ Setup for the game will consist of: pairing your ANSIBLE with your SHIP, and filling the fuel tank.
- ☐ The game will be started by the sound of an air horn.
- ☐ The game ends when a majority of SHIPs on the Battle Pond are in one team's Gate, or when people get bored.
- ☐ At the end of the game, the team with the most SHIPs in its Gate is declared victorious.
- ☐ Any SHIP that enters a Gate is removed from active gameplay and may not exit the Gate into the Battle Pond.
- ☐ SHIPs that become un-fueled dissociate from their paired ANSIBLE and become available for pairing by any other available ANSIBLE.
- ☐ Un-fueled SHIPs are limited to 50% of their maximum speed in any direction.

[5] Definition: Let $\mathbf{c}$ be a vector in the horizontal plane from the base of the of the funnel to the centroid of the SHIP's projection onto the horizontal plane. Let $\mathbf{f}$ be a vector aligned upward along the axis of the funnel, and remaining fixed to the funnel as it moves. The funnel must then be able to be deflected sufficiently far in directions where $\mathbf{c} \cdot \mathbf{f} < 0$ such that the funnel can fully empty of water under gravity.

- ☐ When un-fueled SHIPs become fueled, they un-pair from any paired ANSIBLE and revert to being loyal to their home team by accepting pair requests only from that team's ANSIBLEs.
- ☐ Any paired ANSIBLE may voluntarily un-pair from its SHIP at any time. The SHIP then reverts to a pairing state, limited by fuel tank level as clarified above.
- ☐ Any SHIP found to not be in compliance with the fuel level indicator will be forcibly placed in their opposing team's Gate.

Communications:

- ☐ Communications between the SHIPs and ANSIBLEs will take place over an SPDL-supplied 802.15.4 radio (Xbee24) using the Non-Beacon API mode of operation.
- ☐ Each XBee module will communicate with your device at 115 200 baud.
- ☐ Any ANSIBLE should be capable of controlling any SHIP.
- ☐ Once a game begins, communication will take the form of bidirectional communications between a SHIP and its paired ANSIBLE.
- ☐ Each SHIP and ANSIBLE will be assigned a unique ID in the form of the source address of each SPDL-supplied radio.
- ☐ The details of the communications protocol will be defined and specified by a Communications Committee, which will consist of one member from each project group. The specification must be in a written form and with sufficient detail that someone skilled in ME218 material could implement it.
- ☐ In order to better balance the workload and learning among team members, each of the following tasks must be completed by a different member of the team:
  - serve on the communications committee.
  - implement communications on the SHIP.
  - implement communications on the ANSIBLE.
- ☐ The class communications protocol must include a procedure for validation of communication between the SHIP and ANSIBLE. The SHIPs must provide a visual indication of when a functioning communications link between the SHIP and ANSIBLE exists. The "current controlling team" display is sufficient to meet this requirement.
- ☐ The SHIP will respond to the first received request for control from an eligible ANSIBLE by sending a message back to the requesting ANSIBLE confirming receipt. At this time, the SHIP will also manipulate its display of the current controlling team to match that of the newly-paired ANSIBLE.
- ☐ If a SHIP receives a request for control while it is already under control, it will silently ignore the request.
- ☐ Within 100 ms of un-pairing from its paired ANSIBLE, a SHIP must reset its display of current controlling team.
- ☐ A ANSIBLE may issue messages to SHIP at a rate not to exceed 5 Hz.

General Requirements:

- ☐ At a minimum, either the ANSIBLE or the SHIP must contain two actively communicating processors. There is no class-imposed upper limit on the number of processors employed.
- ☐ You are limited to an expenditure of **$200.00/team** for all materials and parts used in the construction of your project. Materials supplied to each team by SPDL, from the lab kit, or the Cabinet Of Freedom do not count against the limit. All other items count at their fair market value.
- ☐ A project logbook must be maintained for each group. An online blog is appropriate to meet this requirement as long as it is made available to the teaching staff for review. This log should reflect the current

state of the project, planning for the future, results of meetings, designs as they evolve, etc. The project logbook will be reviewed at irregular intervals for evaluation.

- ☐ A report describing the technical details of the system will be required. The report should be of sufficient detail that a person skilled at the level of ME218c could understand, reproduce, and modify the design. The report must be in website format, and be suitable for posting on the SPDL site.
- ☐ SHIPs or ANSIBLEs based substantially on purchased platforms are not allowed.
- ☐ All projects must respect the spirit of the rules. If your team is considering anything that may violate the spirit of the rules, you must consult a member of the teaching staff.

Safety:

- ☐ Both the SHIPs and the ANSIBLEs should be safe, both to the user and the spectators.
- ☐ Intentionally disabling or damaging other SHIPs is not allowed. Prohibited actions include, but are not limited to, the following: ramming at excessive speed (as determined solely at the discretion of the teaching staff).
- ☐ No part of the SHIP may become ballistic, with the exception of water sourced from the Battle Pond.
- ☐ Approved small portable electronic devices may now be used during taxi, take-off, and landing.
- ☐ The teaching staff reserves the right to disqualify any device considered unsafe.

Checkpoints

Design Review:

On **5/8/18** we will conduct a design review, one team at a time. Each team should prepare a few images showing your proposed designs for both the SHIP and the ANSIBLE. You will have 5 minutes to walk us through your ideas. **The focus should be on system level concepts, not detailed hardware or software.** We will spend the balance of the time giving feedback and asking questions. In addition to your concepts, you must present, in printed form, your plan for the development, integration and testing steps that you will follow to complete the project. The plan must identify what functionality you will demonstrate at the two checkpoints and the project preview along with the test procedures that you will use to prove that your team has met the checkpoint. Checkpoint tests must follow an incremental integration strategy with each successive checkpoint demonstrating all of the functionality of the prior checkpoint(s) as well as the new functionality. This plan must be approved by the teaching staff. If we feel that it is seriously flawed, we will ask you to revise and resubmit the following day.

I want you to try things that no one has ever tried because they're absolutely stupid.

Ender Wiggin

First Draft of Communications Standard:

Due by 5:00 pm on **5/9/18**. Karl will meet with the communications committee on the evening of 5/10/18 to provide feedback on the specification.

Ender's anger was cold, and he could use it. Bonzo's was hot, and so it used him.

Ender's Game

Communications Standard:

Due by 5:00 pm on **5/12/18**. This is the working draft of the communications standard.

So the whole war is because we can't talk to each other.

Ender Wiggin

First Checkpoint:

On **5/15/18**, you must demonstrate your approved 1st checkpoint functionality according to your defined testing procedure.

The final working version of the communications standard is due. No further changes are allowed to the standard. This protocol will be evaluated with respect to its completeness and suitability for the proposed system. Note: this is a functional evaluation only. The focus should be on demonstrating functional hardware and software. You may submit for approval a final revision of your checkpoint plan at this time.

Human beings didn't evolve brains in order to lie around on lakes.

Valentine Wiggin

Second Checkpoint:

On **5/22/18**, you must demonstrate your approved 1st and 2nd checkpoint functionality according to your defined testing procedure. The functionality demonstrated at this time must include full implementation of the communications protocol, including pairing and graceful un-pairing (and not just forcible timeout).

Remember - the enemy's gate is down.

Ender Wiggin

Project Preview:

At the Project Preview on **5/25/18**, each team must demonstrate (in addition to the 1st & 2nd checkpoints' functionality) your approved project preview functionality. The functionality demonstrated at this time must include a demonstration of interoperability between at least 2 teams' SHIPs and ANSIBLEs.

We have evolved to survive. And the way we do that is by straining and straining and, at last ... giving birth to genius.

Col. Hyrum Graff

Grading Session:

During the Grading Session on **5/29/18**, each team will be required to demonstrate the ability to successfully participate in a game. This will include

1. Establishing communications between your SHIP and ANSIBLE and between your SHIP and the ANSIBLE from another team.
2. Navigating a SHIP from the initial position and successfully inducing at least one lawmaker to pass through a specified revolving door.
3. Displaying the correct status of communications on both the ANSIBLE and the SHIP.

A detailed grading check-off procedure will be published at a later date.

You will be about to lose, Edner, but you will win.

Mazer Rackham

Public Presentation:

This will take place on **5/30/18** starting at 5:00 pm at the Terman Pond (aka the Battle Pond). At this event, members of the public will be encouraged to act as operators of the ANSIBLEs.

Survival first, then happiness as we can manage it.

Mazer Rackham

Report:

Draft due on **6/4/18** by 4:00 pm. The final version (with revisions incorporated) is due by 5:00 pm on **6/8/18**.

Then I'll tell the truth. We're allowed to do that, in emergencies. We can't plan for everything, you know.

Col. Hyrum Graff

Celebration:

A celebration of the past 3 quarters of ME218 will take place at the Alpine Inn on **05/31/18** starting at 3:00 pm. Mark your calendars now and save the date.

We are, when the cause is sufficient, insane.

Julian "Bean" Delphiki

Evaluation

Performance Testing Procedures:

One or more of the team members will demonstrate the SHIP and ANSIBLE during the first & second checkpoints and project preview. Members of the teaching team will operate the SHIP via the ANSIBLE during the grading session.

Grading Criteria:

- ☐ **Concept (15%)** This will be based on the technical merit of the design and coding for the machine. Included in this grade will be evaluation of the appropriateness of the solution, as well as innovative hardware, software and use of physical principles in the solution.
- ☐ **Implementation (15%)** This will be based on the prototype displayed at the evaluation session. Included in this grade will be evaluation of the physical appearance of the prototype and quality of construction. We will not presume to judge true aesthetics, but will concentrate on craftsmanship and finished appearance.
- ☐ **First Checkpoint (10%)** Based on the results of the performance demonstrated on 5/15/18.
- ☐ **Second Checkpoint (10%)** Based on the results of the performance demonstrated on 5/22/18.
- ☐ **Preliminary Performance (10%)** Based on the results of the performance demonstrated during the Project Preview.
- ☐ **Performance (15%)** Based on the results of the performance testing during the Grading Session.
- ☐ **Report (10%)** This will be based on an evaluation of the report. It will be judged on clarity of explanations, completeness and appropriateness of the documentation.
- ☐ **Report Review (5%)** These points will be awarded based on the thoroughness of your review of your partner team's report. Read the explanations, do they make sense? Review the circuits, do they look like they should work?
- ☐ **Log Book (5%)** This will be evaluated by the evidence of consistent maintenance as well as the quality and relevance of the material in the log book.
- ☐ **Housekeeping (5%)** Based on the timely return of SPDL components, cleanliness of group workstations as well as the overall cleanliness of the lab. No grades will be recorded for teams who have not returned all loaned materials.

Resources

Websites:

SparkFun	Seeed Studio	Jameco
Mouser	Newark	Ponoko
Adafruit	Hackaday	DigiKey
McMaster-Carr	HobbyKing	ServoCity

You may also find PlantUML and PlantText helpful for creating message sequence diagrams.

Local Stores:

J&M Hobby House in San Carlos
Jameco in Belmont
TAP Plastics in Mountain View

Gems of Wisdom:

Be sure to check out The ME218 Archive for guidance from past generations.

Appendix A: Fuel Tank Communication Protocol

Connection Interface:

The Fuel Tank will have a male Molex KK254 connector. When looking at the connector on the fuel tank with the key up, Pin 1 is to the left.

Pin	Name	Function
1	V_{dd}	Power to the Fuel Tank; 3.3 V @ 100 mA
2	GND	Ground reference for the Fuel Tank
3	RX	Received serial data into the Fuel Tank
4	TX	Transmitted serial data from the Fuel Tank

Electrical Specifications:

Parameter	Min	Max	Unit
V_{IH}	$0.65V_{dd}$		V
V_{OH}	$V_{dd} - 0.4$		V
V_{IL}		$0.35V_{dd}$	V
V_{OL}		0.4	V
I_{IH}, I_{IL}		± 1	µA
I_{OH}	-20		µA
I_{OL}	20		µA
All specifications at $V_{dd} = 3.3$ V			

Serial Communication Specification:

The Fuel Tank will communicate using a serial interface operating with eight data bits, no parity, and one stop bit. The serial communication will be at 9600 baud.

Protocol Definition:

Communication between the Fuel Tank and your SHIP will take place in two modes. While the Fuel Tank has fuel in it, the Fuel Tank will respond to queries from your SHIP with a single byte indicating the current level of fuel remaining. Immediately upon fuel running out, and thereafter once every second, the Fuel Tank will transmit a single byte indicating that the Fuel Tank is empty.

SHIP to Fuel Tank Bytes: The meaningful values for the command bytes from the SHIP to the Fuel Tank are shown in the following table:

Command	**Meaning**
`0xAA`	Query the current fuel status

Fuel Tank to SHIP Bytes: Messages from the Fuel Tank to the SHIP will always consist of a single byte:

FS: Fuel Status Information Byte

COMP3	COMP2	COMP1	COMP0	EMPTY	FUEL2	FUEL1	FUEL0
bit 7							bit 0

bit 2-0 **FUEL<2:0>:** Current Fuel Level
Current fuel level in counts; intervals are guaranteed to be repeatable but not uniformly spaced.

bit 3 **EMPTY:** Current Fueled/Empty Status
`0` = Fuel Tank is completely depleted. In this case, `FUEL<2:0>` should be ignored.
`1` = Fuel Tank has fuel.

bit 7-4 **COMP<3:0>:** Error checking bits
`COMP<3:0>` will always contain the complement of the lower order bits `FS<3:0>`.