Gridtape Assembly Instructions

(Last updated 01/11/2024)

Custom machining notes

Piezo chamber

1. QF-25 feedthrough (smaract) and QF-25 feedthrough (tension): machine a 16.1mm bore through the center of each blank for the two lemo connectors (the “tension sensor feedthrough” and the smaract feedthrough)
2. The tension sensor roller pin is a 18-8 stainless steel dowel (not in the CAD). It can either be press fit into the roller or press fit into the side supports.

Reel housing

1. Tape roller screws (SS, 4-40 x ⅛ x ⅝ shoulder screw): cut threads with dremel to vent
3. Clean drive rollers, then glue o-rings to drive rollers (preferred vacuum compatible glue)
4. Clean the bearings and re-oil them with vacuum pump oil or vacuum grease

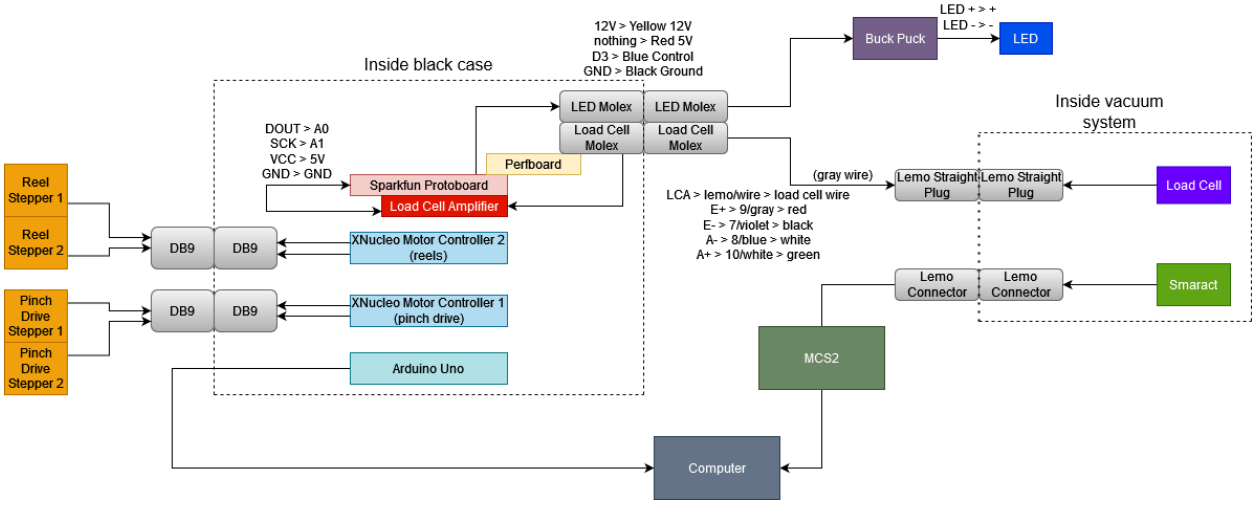
Motors

1. 2x pinch drive timing belt pulleys (MXL timing pulley, ⅛ wide, 15 tooth, 3/16 bore): drill out bore to 5mm (to fit over the stepper motor shafts for the pinch drive)
2. Slip clutch modifications (these are the modifications as seen on xtemgt - this slip clutch modification and assembly may be modified in the future):
    a. 2x slip clutch (0.25” bore adjustable slip clutch with torque range of 0.3 to 32 OZ-IN): drill out the bore on the hub side to 0.312” in diameter and 0.224” deep (to hold the slip clutch timing belt pulley).
    b. 2x slip clutch timing belt pulleys (MXL timing pulley, ⅛ wide, 18 tooth, 3/16 bore): drill out the inside bore to 0.25” in diameter. Press fit into the hub side of the slip clutch.
3. Waterjet:
    a. 2x pinch_drive_clamp_short (⅛” al stock)
    b. 2x reel_drive_clamp_slipclutch (⅛” al stock
4. The takeup rest is made of stainless steel, not aluminum. This is to prevent the aluminum channel from abrading away the takeup rest and permanently altering the alignment of those two components.

Assembly

Electronics Assembly

Wiring Diagram



Pinouts

Pins along the same row connect to one another (example of how to read a row is given for each table).

Stepper Motor pinout
(The first row reads as: the feed pinch drive stepper motor's red wire connects to top DB-9 plug pin 1, the corresponding top DB-9 receptacle connector pin 1 connects to the top motor controller shield ST2 2B block)

Position in Case	Pin Number	Signal	Stepper wire	Shield Input	Shield	Shield Signal	CS	Chain Index	0 direction	Enclosure Port
Top DB-9	1	Feed, Pinch	Red	ST2	Top	2B	A2	0	CCW	Top
	2	Feed, Pinch	Blue	ST2	Top	1B	A2	0	CCW	Top
	3	Feed, Pinch	Black	ST2	Top	1A	A2	0	CCW	Top
	4	Feed, Pinch	Green	ST2	Top	2A	A2	0	CCW	Top

	5	NC								
	6	Feed, Reel	Red	ST2	Bottom	2B	D2	0	CCW	Top
	7	Feed, Reel	Blue	ST2	Bottom	1B	D2	0	CCW	Top
	8	Feed, Reel	Black	ST2	Bottom	1A	D2	0	CCW	Top
	9	Feed, Reel	Green	ST2	Bottom	2A	D2	0	CCW	Top
Bottom DB-9	1	Pickup, Pinch	Red	ST1	Top	2B	A2	1	CCW	Bottom
	2	Pickup, Pinch	Blue	ST1	Top	1B	A2	1	CCW	Bottom
	3	Pickup, Pinch	Black	ST1	Top	1A	A2	1	CCW	Bottom
	4	Pickup, Pinch	Green	ST1	Top	2A	A2	1	CCW	Bottom
	5	NC								
	6	Pickup, Reel	Red	ST1	Bottom	2B	D2	1	CCW	Bottom
	7	Pickup, Reel	Blue	ST1	Bottom	1B	D2	1	CCW	Bottom
	8	Pickup, Reel	Black	ST1	Bottom	1A	D2	1	CCW	Bottom
	9	Pickup, Reel	Green	ST1	Bottom	2A	D2	1	CCW	Bottom

LED pinout

(The first row reads as: 4-pin plug pin 1 is connected to the Arduino Vin, corresponding 4-pin receptacle pin 1 is connected to a wire that goes to Buckpuck V+)

Connector	Pin number	Signal	Buckpuck	Arduino
Right 4 pin	1	12V	V+	Vin
	2	5V	REF	NOTHING
	3	D3	CTL	D3
	4	GND	V-	GND

Load Cell pinout

(The first row reads as: 4-pin plug pin 1 connects to E+ on the load cell amplifier, corresponding 4-pin receptacle pin 1 connects to the gray cable grey wire, which connects to Lemo pin 9 (across the Lemo plug and straight connector), which connects to the load cell red wire)

Connector	Pin number	Signal	Load cell	Lemo Pin	Gray cable color
Left 4 pin	1	E+	Red	9	Grey
(above USB)	2	E-	Black	8	Violet
	3	A-	White	7	Blue
	4	A+	Green	10	White

Motors

There are two motor controller boards (X-NUCLEO-IHM02A1) on the GridTape system. Each can drive two stepper motors. The two pinch drive motors will connect to one controller. The two reel motors will connect to the second controller. The controllers will need to be modified to make them Arduino compatible, but they can physically mount onto an Arduinio Uno board out of the box.

Do note that there is bare bones documentation for Arduino compatibility and one small github library for the Arduino Uno API. The boards are VOLTAGE controlled, not current controlled.

On both boards:

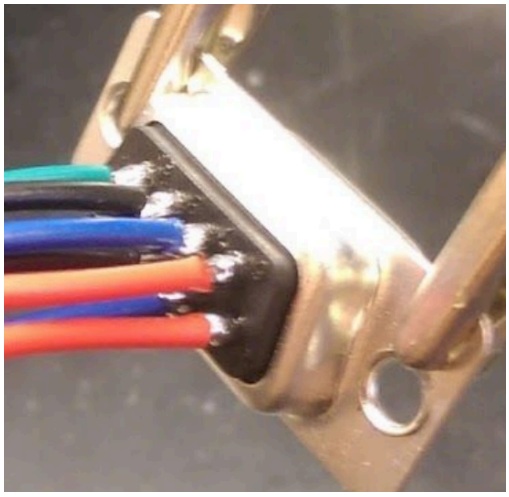
- Unsolder SB40, solder SB41
- Unsolder SB34, solder SB12

On the reel board:

Unsolder SB23, solder SB7

For the boards, the feed side motors always connect to ST2 (see the marking on the x-nucleo board) and the pickup side motors always connect to ST1 (also see the x-nucleo board).

Solder the feed steppers to a single DB9 and the pickup steppers to a single DB9, as shown below (and detailed above):

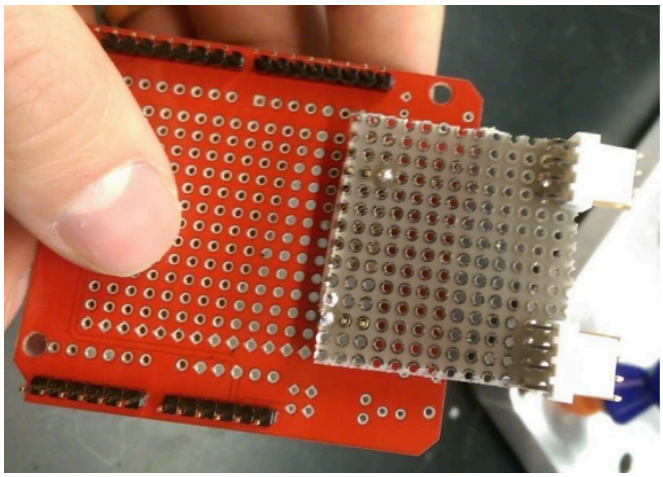


Solder the corresponding DB9's connectors to wires that screw into the terminal blocks of the motor controller boards.

The feed side motor controller stacks on top of the pickup side motor controller, and both then stack on top of the Arduino Uno.

Sparkfun Protoshield to load cell and LED connectors

Cut a 14 hole x 14 hole piece of protoboard and solder it to the edge of a Sparkfun protoshield so that 6 rows of holes hang off the edge on the side of the protoshield that lines up with the USB edge of the Arduino. Solder two 4-pin right angle molex connectors to the far edge of the protoboard. This is so the molex connectors can protrude from the sides of the black case.

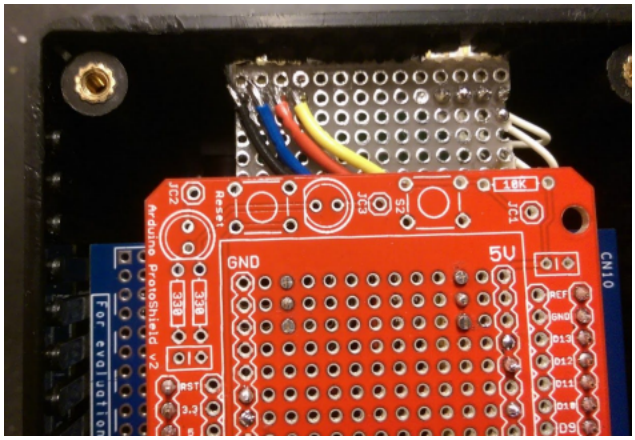


Any 4-pin connector should work, image uses JST connectors

Place the load cell amplifier on the bottom face of the Sparkfun protoshield and solder jumper wires to connect the Arduino, load cell amplifier and the 2x 4 pin connectors. The connectors will be used for the load cell (tension sensor) and LED.

Load cell connector

Consult the table above for the pinout.



The Sparkfun protoshield with attached load cell amplifier and protoboard stack on top of the motor controller boards.

Load cell cabling with Lemo connectors

Use kapton insulated wire and silver solder (for vacuum compatibility reasons) to extend the tension sensor's four wires by about 6in to fit through the T junction. Connect these wires to the Lemo plug (shown below) like so (Load Cell pinout table also shows these connections across the whole load cell path):

- Load cell Red > Plug 9
- Load cell Black > Plug 8
- Load cell White > Plug 7
- Load Cell Green >Plug 10

Lemo plug from the back:

- https://www.mouser.com/datasheet/2/232/HGP_2S_310_CLLPV-1941806.pdf
- Load cell extended wires connect here!
- Dark holes correspond to protruding pins, light holes correspond to enclosed pins

The load cell lemo plug connects to the load cell amplifier via a gray connector cable. The connector cable is composed of a stripped end crimped into a molex connector and a stripped end soldered into a lemo straight connector. The straight lemo connector must be partially disassembled to reach the pins in the back. This cable-lemo join requires an order of operations - take the back screw + spring tensioner off of the lemo straight connector and loop them onto the cable end that you're going to solder to FIRST. Then strip the wires and solder to the back of the connector. And then assemble. Otherwise you will be sad. The gray connector cable is soldered to the lemo straight connector like so (Load Cell pinout table also shows these connections across the whole load cell path):

- Cable Gray > Straight connector 9
- Cable Violet > Straight connector 8
- Cable Blue > Straight connector 7
- Cable White > Straight connector 10

Lemo straight connector from the back

- Gray connector cable goes here!
- Dark holes correspond to protruding pins, light holes correspond to enclosed pins

The gray connector cable is then stripped and the four wires that lead to the load cell amplifier crimped into a molex connector.

LED

Solder jumper wires from the Sparkfun protoshield Vin, D3, and GND to the remaining molex connector . This connector will go to the LED. Consult the table above for the pinout.

Make a 1.5ft yellow, red, blue, black wire bundle. Crimp one end of the wires into a 4 pin molex connector so that it lines up with the molex connector on the protoboard. Crimp the other end of the wires into a 4 pin header socket to attach to the buck puck. Connect the LED- and GND on the buck puck and solder the LED+ and LED- to the LED.

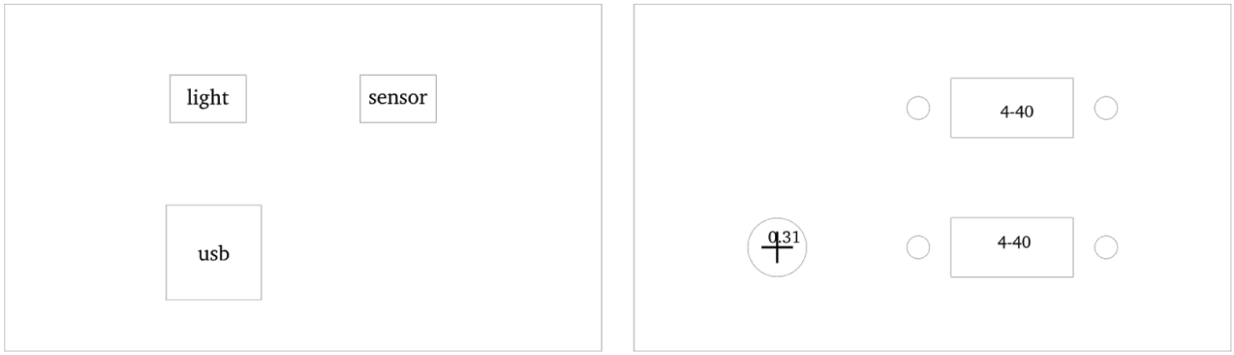
Tap 4-40 holes into a heatsink and lightly fix the LED to the heatsink with some thermal tape. Screw the LED into the heatsink. Double sided tape the buckpuck to the other side of the heat sink and zip tie the heat sink to the LED mount.

Enclosure

Cut access holes on both small faces of the black plastic case.

- Face 1:
    - Arduino USB
    - Two molex connectors
- Face 2:
    - Power plug
    - Two DB9 connectors

Something like the following template (scaled to fit the ends of the enclosure)



Hardware

Deburr parts and make final modifications

1. Channel (top/bottom):
    a. Deburr and polish channel surfaces
    b. Round off channel entrance and exit
2. Make sure piezo plates are flat and burr free
3. Check all oring sealing surfaces

Chamber cleaning

Clean all parts that will go into vacuum with the following:

1. Wipe off any visible dirt
2. Wash in hot water and alconox
3. If possible, place in ultrasonic cleaner for 5 minutes with alconox and water
4. Rinse thoroughly with hot water
5. Rinse with DI water
6. Rinse with Acetone
7. Rinse with 100% ethanol

FIrst assembly! Do follow this in order, the order is kind of important to avoid blocking screws.

1. Piezo chamber
    a. Take the piezo-to-column-flange (front_left_xy_flange) and slip a Viton75-027 o-ring onto the scope insert end and place a Viton75-027 on the flat piezo chamber-side face. Attach the front_left_xy_flange to the column with 4 SS M6x10mm SHCS low profile.
    b. Attach the piezo chamber (chamber_v1) to the piezo-to-column-flange with 4 SS M5x16mm SHCS.
    c. Attach the Smaract piezo stack to the piezo base plate (piezo_baseplate) with 4 M1.6x4mm FH. Attach the piezo base plate to the bottom of the piezo chamber with 4 SS 2-56x3/16 SHCS vented.
    d. Attach the right side of the T in the Lesker KF25 T junction to the side of the piezo chamber with Lesker QF25 Al clamps and Lesker KF25 centering silicone o-ring.
    e. Feed the Lemo feedthrough attached to the Smaract piezo stack through one free arm of the Lesker KF25 T junction.
    f. Attach the load cell mounting block (load_cell_vertical_base_v2) to the piezo chamber with 2 SS 2-56x3/8 SHCS vented.
    g. Unscrew the nut at the Lemo connector attached to the load cell. Feed the load cell through the KF25 flange, then through the nut, then through the remaining free arm of the Lesker KF25 T junction into the piezo chamber. Attach the tension

roller (tension_roller_mount, tension_roller_v2) on top of the wire-free end of the load cell with 2 SS 0-80x1/4 FH. Attach the wire-end of the load cell on top of the load cell mounting block with 2 SS 0-80x1/4 FH.

h. Place a KF25 centering silicone o-ring on each free end of the Lesker KF25 T junction. Take the connector pair of the Smaract Lemo connector and connect the two through a machined KF25 flange (make sure the furrowed face is facing the T junction opening). Take the connector pair of the load cell Lemo connector and connect the two through a second machined KF25 flange (make sure the furrowed face is facing the T junction opening). Put each KF25 flange on the KF25 centering silicone o-ring and clamp each in place with a KF25 wingnut clamp.
i. Place a KF16 centering silicone o-ring on the opening in the flat (no gland) face of the piezo chamber lid (chamber_lid_with_view) and place a KF16 viewport on top of the o-ring. Secure it all down with a KF16 bulkhead clamp. Place a Viton75-036 o-ring in the lid gland and screw it down on top of the piezo chamber with 4 SS 6-32x1/2 FHSC.

2. Channel and Scope
    a. Add Viton 75-122 o-rings to the takeup rest (takeup_rest_insert). Insert it into the right opening of the scope so that the flat side of the through-hole is on the bottom.
    b. Spread a very fine layer of vacuum grease on the lower surface of the bore in the takeup rest.
    c. Tape the channel, ensuring that a doubled up piece of gridtape will slide through the channel with ~15g of force, and insert through the piezo chamber until the end of the channel rests on top of the takeup rest.
    d. Add a Viton 75-219 o-ring to the gland side of the takeup_reel_flange, and attach it to the scope with 2 SS M4x10mm FHSC, so that the screws are on the top half of the flange and the o-ring is pressed flat against the scope.
3. Feed and Pickup Reel housing (instructions for one housing)
    a. Insert the Ferrotec feedthroughs for the pinch drive and the reel motor. DO NOT fix them in place yet.
    b. Slide the inner spacer (inner_spacer) into the center of the idle roller (roller). Place a ⅛ shaft ¼ flanged bearing on either side of the through-hole in the idle roller. Slide a SS 4-40x1/8 x ⅝ shoulder screw through the bearings. The roller spacer (roller_spacer) should be slid onto the thread end of the shoulder screw - this is so the idle roller is positioned correctly when the shoulder screw is screwed into the housing. .
    c. Place the active roller (drive_roller) and the idle roller in contact so that the o-rings on the active roller fit inside the outermost flanges of the idle roller. With the active roller and the idle roller together, slide the active roller onto the upper Ferrotec feedthrough shaft inside of the reel housing and screw in the shoulder screw into the threaded hole closest to the scope. Make sure to keep the roller as

in-line with one another as possible. Mount the active roller on the feedthrough shaft with 2 SS 8-32x1/4 set screw vented.

d. Mount the reel hub (reel_adapter_screw_set_3f16) onto the lower Ferrotec feedthrough shaft inside of the reel housing with SS 8-32x1/4 set screw vented. Make sure that the reel hub is aligned with the pinch drive.
e. Add a Viton 75-027 o-ring to the reel face of the reel flange (reel_housing_flange) and secure it to the reel housing with 4 4-40x3/8 FHSC.
f. Add a Viton 75-027 o-ring to the QF16 reel flange (reel_housing_to_qf16_flange) and secure it onto the open window (the one facing away from the scope) in the side of the reel housing with 4 4-40x3/8 FHSC screws. Place the KF16 centering silicone o-ring onto the opening in the flange, set the KF16 viewport on the centering silicone o-ring, and then secure it down with a KF16 bulkhead clamp.
g. And split depending on feed/pickup reel:
    i. Feed reel: Add pinch drive motor mount (pinch_drive_clamp_short) and reel motor mounts (reel_drive_clamp_slipclutch) with 6 SS 4-40x3/8 SHCS. Add the upper left screw (SS 6-32x7/16 FHSC)from the reel housing flange into the piezo chamber and then fix the Ferrotec feedthroughs in place with the Ferrotec clamps (ferrotec_clamp) and 4 SS 2-56x5/16 FHSC each. Finish attaching the reel housing flange to the piezo chamber with 3 SS 6-32x7/16 FHSC.
    ii. Pickup reel: Attach reel housing flange (reel_housing_flange) to takeup reel flange (takeup_reel_flange) with 4 SS 6-32x7/16 FHSC. Add the pinch drive motor mount (pinch_drive_clamp_short) and reel motor mounts (reel_drive_clamp_slipclutch) with 6 SS 4-40x3/8 SHCS. Fix the Ferrotec feedthroughs in place with the Ferrotec clamps (ferrotec_clamp) and 4 SS 2-56x5/16 FHSC each.
h. Mount the pulleys on the Ferrotec feedthroughs. Loop the corresponding belts over the pulleys.
i. Mount the reel motor shaft adaptor (shaft_adapter_slipclutch) to the reel drive motors, mount the pulley onto the slipclutch, then mount the slipclutch onto the shaft adaptor.
j. Mount the motors onto the pinch drive motor mounts and reel motor mounts. Make sure to loop the belt around the motor pulley and to give some tension on the belt when screwing in the motors with 16 SS M2.5x6mm BHSC.

Testing

Vacuum Testing (off scope)

Vacuum test the following:

- Reel housings (feed and pickup)
    - With no extra flanges

        - WIth all extra flanges
- Piezo chamber
    - Alone
    - With KF-25 Tee
    - With reel housings

Movement testing

Test that piezos move with no reported errors
Test pinch drive movements and note directions
Test tape movement