

Fast Filter Switcher (aka Filter Switcher v2)

Operation modes and workflow

ppicot

Ver 180807 for software v0.43: cheatsheet (last page) only updated.

Introduction

Filter Switcher switches cylindrical x-ray filters within the bore of the GE eXplore SpectCZT microCT scanner, to enable dual energy imaging.

Previously, filters were switched between two nominally identical scans, a few minutes apart. Subject animal motion during the scan acquisition caused misregistration between the two scans, causing dual-energy processing artifacts.

V2 is a faster version of the V1 design, and intended to switch filters on every view during the scan, about every second or two. It interacts with the ECG input and view pulse output signals from the scanner for synchronization, and optionally with an ECG or respiratory signal from the animal being scanned.

This document describes the workflow, user and scanner interfaces, and software design. The last page is a printable mode “cheatsheet” to keep with the device.

Hardware Overview

The hardware is functionally similar to the V1 design. The components are:

1. Erbium-copper filter cylinder: same as V1 design, mounted on a new support rod/leadscrew nut mount.
2. Leadscrew+high power stepper stage, with home switch.
3. Cable, with gender adapter, to control box
4. Control box containing:
 - a. Compumotor OEM750X drive/indexer
 - b. Arduino Due controller
 - c. User interface:
 - i. 3 buttons with green, red, green LEDs
 - ii. 10-position rotary switch
 - iii. power switch
 - d. Electrical interface:
 - i. BNC input from scanner View pulse output
 - ii. BNC output to scanner ECG input
 - iii. USB programming/monitor port
 - iv. 9-pin connector to motor
 - e. Associated power supply, interface, fan hardware
5. External 48V 3A power supply

Proposed workflows

Mode 1: Same as original V1 mode 1: 26 views per switch, plus 20 brightfields

Mode 2: Same as original V2 mode 2: 920 views per switch, plus 20 brightfields

Mode 3: Same as original V1 mode 3: 12020 views per switch, plus 20 brightfields

Mode 4: Fluoro, ignore view triggers, manual switch filters

Mode 5: ECG gated, scanner master (MD whiteboard 1st mode)

- Filter Switcher is prepositioned and armed in Filter 1 state
- Scanner is set up for “dual-energy” (i.e., two-phase ECG) scan, and started
- animal monitor (or external trigger) produces ECG pulse, sent to scanner
- scanner triggers whenever ready, acquires 1st energy view and sends Trig pulse to Filter Switcher
- Filter Switcher waits for exposure to end (~50 milliseconds), then moves filter to Filter 2 state
- Scanner completes its view data acquisition and arms for the next ECG
- Scanner triggers on next ECG pulse, acquires 2nd energy view and sends View pulse to Filter Switcher
- Filter switcher moves back to Filter 1
- Scanner moves to the next view location
- **Important:** Assumption is that the filter switcher will complete its motion before the scanner completes its view data acquisition and triggers on the next ECG pulse. ECGs slower than 1.25 Hz (75 bpm) will guarantee this. (Optimum is 1.1 Hz (67 bpm), where scanner skips only one ECG during gantry movement to next view)

Mode 6: (todo) ECG gated, filter master (MD whiteboard 2nd mode). Similar to Mode 5, but filter switcher is the ECG source and thus timing master.

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- Scanner triggers on next ECG pulse, acquires 2nd energy view and sends View pulse to Filter Switcher
- Filter switcher moves back to Filter 1

- Scanner moves to the next view location
- **Important:** Assumption is that the filter switcher will complete its motion before the scanner completes its view data acquisition and triggers on the next ECG pulse. ECGs slower than 1.25 Hz (75 bpm) will guarantee this. More optimum is 1.1 Hz (67 bpm), where the scanner skips only one ECG trigger during gantry movement to the next view)

Mode 7: (todo) Double rate scanner master synchronized run (MD whiteboard 3rd "lower extrem not gated" mode 1/ 2x views)

- On scanner trigger, filter switches only every other view, requires data unscrambling after the scan, and possibly rotation of the volume by ½ a view angle?

Mode 8: (todo) No ECG, Filter switcher master synchronized run (MD whiteboard 3rd mode 2/ force gate)

- Same as mode 7, but filter generates triggers for scanner

Mode 9: Level control: Input BNC level controls filter state. Actual filter state echoed on output BNC upon move complete.

Mode 10: (todo) Set parameters via serial terminal

(Future) Work to do:

1. Design, print, add mode legend on top
2. Repair/strengthen/redesign pushrod & filter mounting. The current version:
 - a. rubs on plastic supports or the bed, decreasing max speed
 - b. collides with the bore tubes on entering the bore
 - c. jams easily
 - d. and appears to not locate repeatably, producing artifacts.
3. Consider upgrade to a motor with an encoder
4. Add UHMWPE sltape for bearing for filter cylinder?
5. For speed increase: how to determine when gantry has completed motion / how to minimize delays.
6. Figure out how to ignore the brightfield exposures (by having user press a start button after brightfields are done?), or quickly reset the filter position:

Proposed operating methods

The user interface is three buttons and a rotary switch.

Button 1 is Start/Erbium/Down, illuminates green

Button 2 is Stop/Copper/Up, illuminates red

Button 3 is Home/Enter/abort, illuminates green

Rotary switch selects mode: Blinking LEDs indicate active buttons

Modes 1, 2, 3:

Mode 4: Manual filter w/ECGs out: all 3 LEDs blink until one is pressed

- a. Start selects Erbium, solid green illuminates
- b. Stop selects Copper, solid red illuminates
- c. Home goes to home position, illuminates its red

Mode 5: Automatic 2-phase acquisition: Home button blinks until pushed/homed

- d. Start starts sequence, starting with Erbium (Green/Red alternate)
- e. Stop stops sequence, stopping on Erbium (Green illuminates)
- f. Home homes to Erbium at beginning, or aborts while running

2. External control mode: Home button blinks to start, then goes solid. External BNC input level adjusts filter state.

- a. Red/Green LEDs indicate state

3. Set 1-2 acquisition delay time

4. Set view increment dwell time

5. Set filter shift speed

6. Custom program

7. Custom program

8. Custom program

9. Custom Program

Normal Acquisition

In normal operation, the switcher controls CT scanner acquisition via the scanner ECG input (BNC, TTL). The scanner is configured to acquire two ECG time points per view.

The flow is as follows:

1. Set up the switcher location, plug it in, turn it on
 - a. (Home button will be flashing)
2. Select a switcher program mode (rotary switch)
 - a. (Home button will still flash)
3. Press Home switch
 - a. (Switcher will home to Erbium. Start button will flash)
4. Setup and start a two-phase ECG-gated scan on the CT scanner
5. Wait until the scanner is ready to begin and waiting for ECG input
6. Start the switcher (pushbutton)
7. Sequence begins:
 - a. Switcher outputs ECG trigger 1 for Erbium acquisition
 - i. Scanner acquires phase 1
 - b. Switcher waits fixed delay (~0.2 s) to wait for scanner view acquisition.
 - c. Switcher moves filter to Copper(~0.4 s)
 - d. Switcher outputs ECG trigger 2 for Copper acquisition
 - i. Scanner acquires phase 2
 - e. Switcher waits fixed delay (~0.2 s) to wait for scanner view acquisition.
 - f. Switcher moves filter to Erbium (~0.4 s)
 - g. Loop indefinitely to (a), until Stop or Home/abort button is pressed

FFS: Fast Filter Switcher

Controls:

Left Button: Lights green when in Erbium position. Selects Erbium filter (mode 4)

Middle Button: Lights red when in Copper position. Selects Copper filter (mode 4)

Right button: Starts a new mode. Resets motor (mode 4)

OPERATING MODES: Select with rotary switch, confirm with Right button.

1. **Slow Switch 26:** Switch filters after 26 exposures (same as v1 mode 1).
2. **Slow Switch 920:** Switch after 920 exposures (same as v1 mode 2).
3. **Slow Switch 12020:** Switch after 12020 exposures (same as v1 mode 3).
4. **Manual switch:** ignore triggers, switch filters by user control (= v1 mode 4).
5. **Fast switch:** Alternate filter after each exposure trigger from scanner. Assumes scanner is receiving ECG triggers at a suitable rate (period > 400 ms).
6. **Fast Switch, filter master, fixed rate:** FFS is master, sends trigger to scanner at fixed 900 ms period. Waits for exposure before switching filter. REQUIRES BOTH ECG AND TRIG CABLES.
7. **Same as Mode 6, but for liquid filter.**
8. **Fast Switch, Synchronized Double Rate:** FFS sends FOUR triggers to scanner for each filter position. REQUIRES BOTH ECG AND TRIG CABLES.
9. **External Control:** Filter state is determined by BNC input level.
10. **Motor OFF & Serial Console:** Turns motor off for safe bed motion and manual positioning. Serial port console for Parameter editing.

Connections:

Modes 1, 2, 3 or 5: Connect Scanner Trigger Out to FFS Input.

Mode 4 or 10: No connection required.

Mode 6 : Connect FFS Output to Scanner ECG input.

Mode 6, 7 or 8: Connect FFS Output to Scanner ECG input, and connect Scanner Trig Output to FFS Input.

Mode 9: Connect external control device to FFS Input.

STATUS OUTPUT

In Modes 1-5 and 9, FFS Output follows filter position: High for Copper, Low for Erbium. The USB port outputs timing and status information for logging, if desired (9600 baud).

Error condition: if the three LEDs are blinking fast-slow-fast then there is noise on the input trigger line. Press the right button to clear the error and again to restart the mode.