HDMI CEC (Consumer Electronics Control)

Status Report

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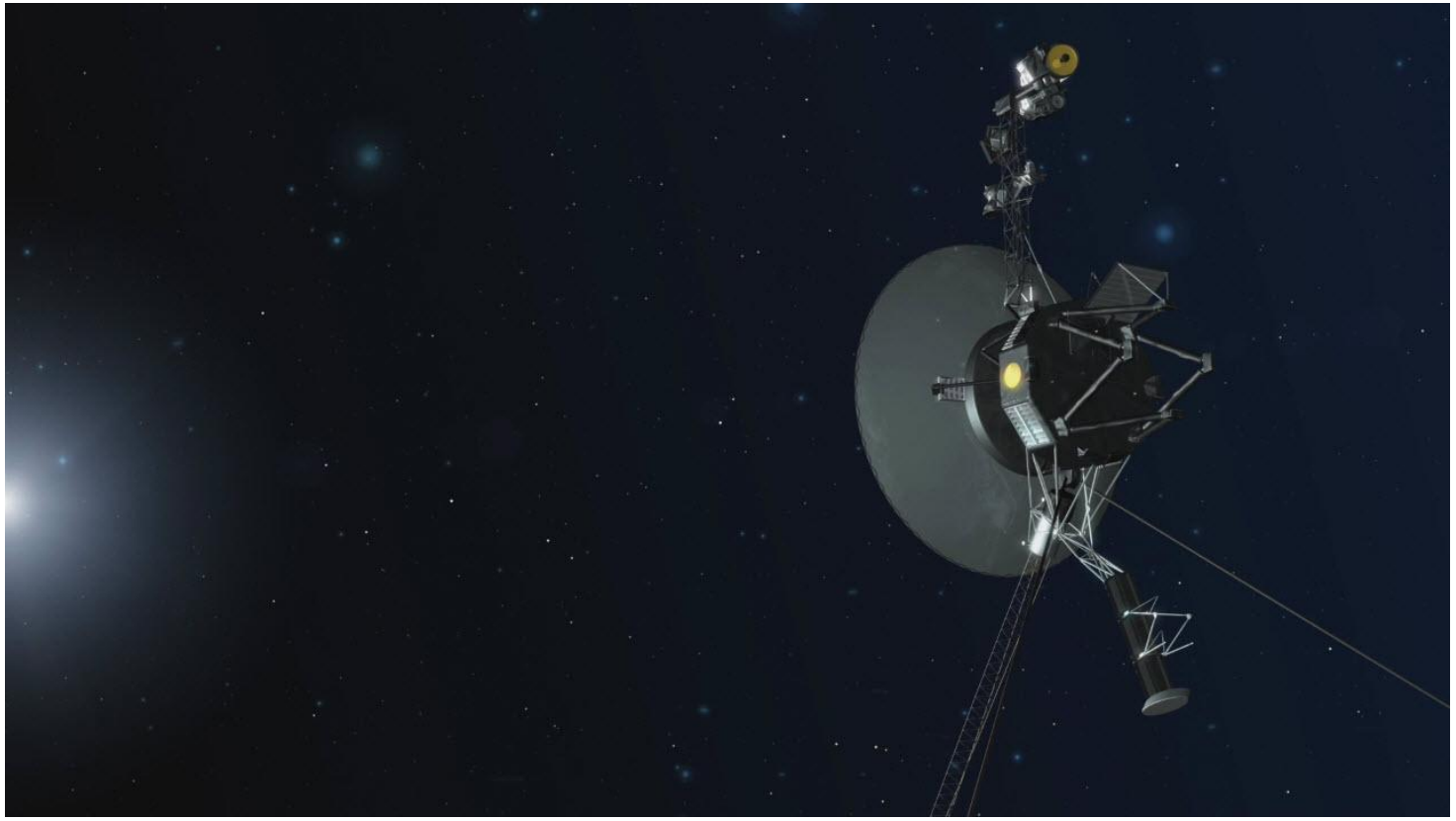
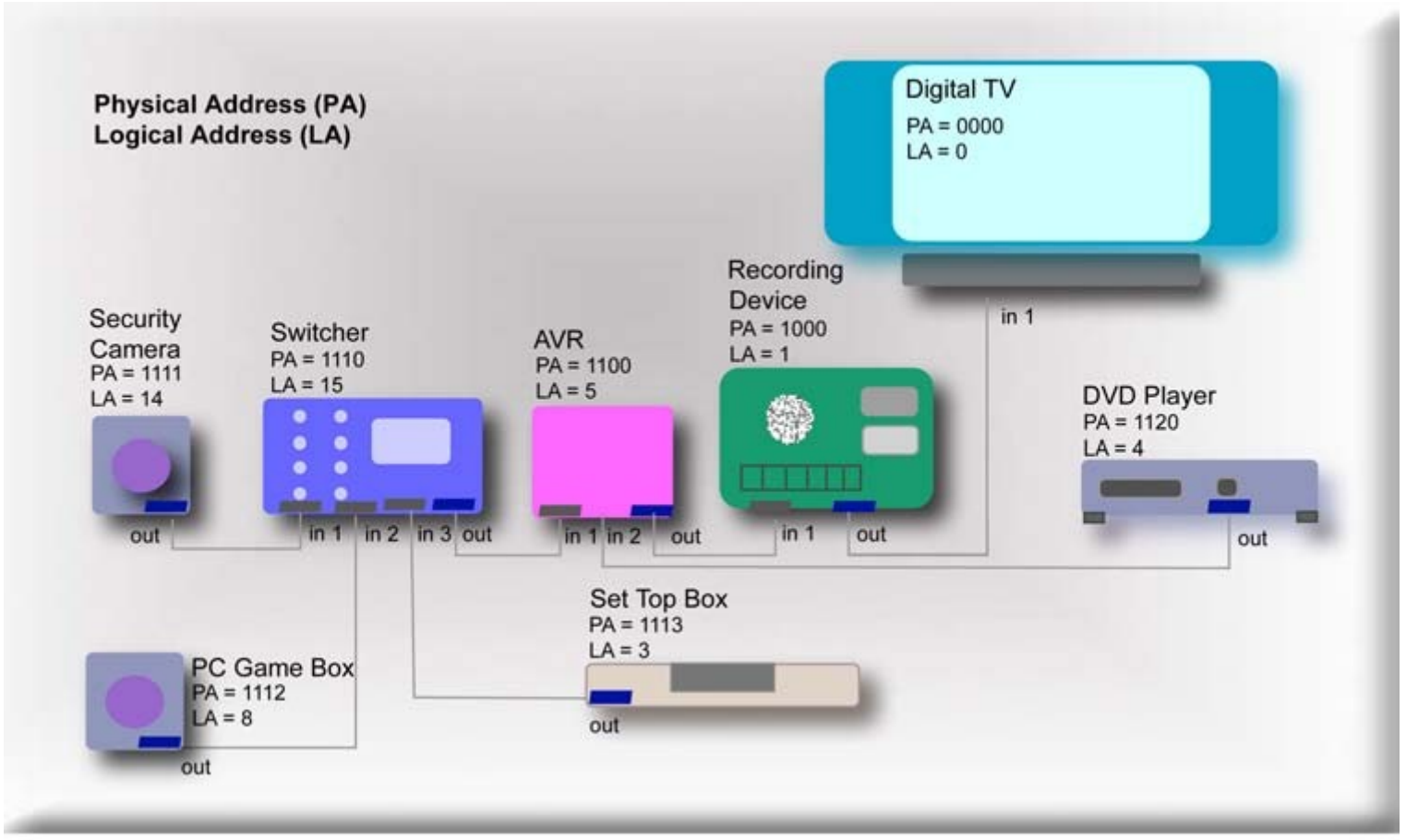


Voyager 1 (launched Sep 5, 1977) @ 21 billion km (13 billion miles, 140 AU): 1400 bits/s



CEC @ 1 meter: 400 bits/s

What Is CEC?

Consumer Electronics Control

- An optional supplement to HDMI using pin 13 of the HDMI connector.
- Provides high-level control functions between the various audiovisual products in a user's environment.
- Based on the old AV.link scart standard (EN 50157-2-[123]).
- Implemented in HDMI receivers/transmitters and USB HDMI-passthrough devices.
- Data packets: 1 header byte + 0 to 15 data bytes.
- Very, very slow data rate ~400 bits/s.

Physical Address

Physical address: Hierarchy placement

Range:	0.0.0.0 - F.F.F.F	
Root device:	0.0.0.0:	HDMI Sink, typically a TV
First device:	1.0.0.0:	Device connected to HDMI port 1 on root device
Second device:	2.0.0.0:	Device connected to HDMI port 2 on root device
Third device:	2.1.0.0:	Device connected to HDMI port 2 on first device
Invalid:	f.f.f.f:	There is no physical address. CEC is typically disabled in this case

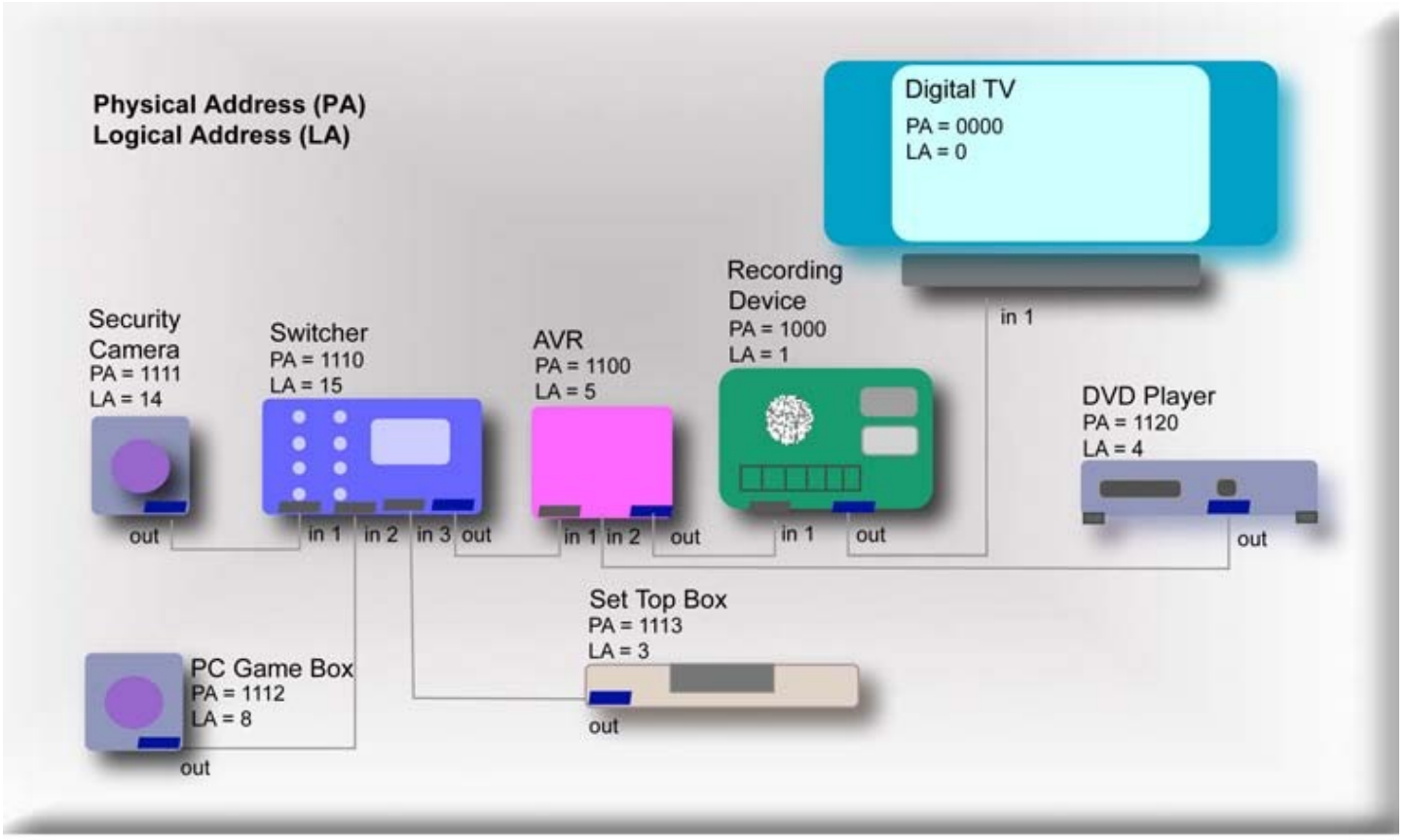
Sources get their Physical address from the EDID which is obtained from the sink.

Logical Address

Logical address 0-15: product type dependent.
Not really an address, more like a nickname.

0: TV (root device)
1: Recording device 1
2: Recording device 2
3: Tuner 1
4: Playback device 1
5: Audio system
6: Tuner 2
7: Tuner 3
8: Playback device 2
9: Recording device 3
10: Tuner 4
11: Playback device 3
12: Backup 1
13: Backup 2
14: Specific use
15: Unregistered (as Initiator address)
Broadcast (as Destination address)

Topology Example



Trade Names

- Anynet+ (SAMSUNG)
- BRAVIA Link (Sony)
- Kuro Link (Pioneer)
- EasyLink (Philips)
- SimpLink (LG)
- VIERA link (Panasonic)

Why Implement CEC?

End-User Features

- One Touch Play: allows a device to be played and become the active source with a single button press.
- System Standby: enables the user to switch all devices to the Standby state with one button press.
- One Touch Record: offers a What You See Is What You Record (WYSIWYR) facility, meaning that whatever is shown on the TV screen is recorded on a selected Recording Device.
- Timer Programming: allows the user to program the timers in a Recording Device from an EPG running on a TV or STB.
- Deck Control: enables a device to control (e.g. play, fast forward etc.) and interrogate a Playback Device (a deck).

  blue == well-tested by cec-compliance.

End-User Features

- Tuner Control: allows a device to control the tuner of another device.
- Device Menu Control: enables a device to control the menu of another device by passing through user interface commands.
- Remote Control Pass Through: enables remote control commands to be passed through to other devices within the system.
- System Audio Control: allows an Audio Amplifier / Receiver to be used with the TV. The volume can be controlled using any the remote controls of any suitably-equipped devices in the system.

Supporting Features

- Device OSD Name Transfer: enables devices to upload their preferred OSD name to the TV. The TV can then use this name in any menus associated with that device.
- Device Power Status: allows the current power status of a device to be discovered.
- OSD Display: enables a device to use the on-screen display of the TV to display text strings.
- Routing Control: allows the control of CEC Switches for streaming of a new source device.
- System Information: queries the system to determine device addresses and language.
- Dynamic Audio Lipsync: used by sinks to announce their audio latency (CEC 2.0 feature, but allowed for CEC 1.4 devices as well).

Supporting Features

- Vendor Specific Commands: allows a set of vendor-defined commands to be used between devices of that vendor.
- Audio Rate Control: allows an Amplifier to fractionally increase or decrease the playback rate of an audio source.
- Audio Return Channel Control: controls the Audio Return Channel (ARC) part of the HDMI Ethernet and Audio Return Channel (HEAC).
- Capability Discovery and Control: controls HDMI Ethernet Channel (HEC) part of HEAC.

How Is CEC Implemented?

CEC Framework

- Creates a /dev/cecX device node.
- The driver determines the level of control userspace is allowed.
- Drivers implement the low-level CEC adapter operations.
- The framework deals with the details of the protocol and the asynchronous aspects.
- The framework processes the core CEC messages automatically (unless userspace enables passthrough mode).
- The framework allows monitoring the CEC line.
- Core code is in drivers/media/cec.
- Static inlines to assemble/decode CEC messages are in include/uapi/linux/cec-funcs.h.
- Optionally integrates with the kernel's remote control framework for the CEC Remote Control Passthrough Feature.

CEC Adapter Driver

```
struct cec_adap_ops {
        /* Low-level callbacks (blue == required) */
        int (*adap_enable)(struct cec_adapter *adap, bool enable);
        int (*adap_monitor_all_enable)(struct cec_adapter *adap, bool enable);
        int (*adap_log_addr)(struct cec_adapter *adap, u8 logical_addr);
        int (*adap_transmit)(struct cec_adapter *adap, u8 attempts,
                             u32 signal_free_time, struct cec_msg *msg);
        void (*adap_status)(struct cec_adapter *adap);
        void (*adap_free)(struct cec_adapter *adap);

        /* Optional high-level CEC message callback */
        int (*received)(struct cec_adapter *adap, struct cec_msg *msg);
};

void cec_transmit_done(struct cec_adapter *adap, u8 status, u8 arb_lost_cnt,
                       u8 nack_cnt, u8 low_drive_cnt, u8 error_cnt);
void cec_received_msg(struct cec_adapter *adap, struct cec_msg *msg);
```

CEC API

- `CEC_ADAP_G_CAPS`: returns the capabilities of the CEC adapter.
- `CEC_ADAP_G/S_PHYS_ADDR`: get/set the physical address for the CEC adapter.
- `CEC_ADAP_G/S_LOG_ADDRS`: get/set the logical addresses and other fixed information for the CEC adapter.
- `CEC_G/S_MODE`: get/set the mode of the filehandle. Filehandles can be in initiator mode and/or in follower mode. In initiator mode they can transmit CEC messages and receive replies. In follower mode they can receive CEC messages and are expected to handle those messages if needed.
- `CEC_RECEIVE/TRANSMIT`: receive and transmit CEC messages. Optionally `CEC_TRANSMIT` can wait for a reply.
- `CEC_DQEVENT`: event handling: when the physical or logical addresses change userspace will be informed. Important to detect disconnect/connect changes.
- `/sys/kernel/debug/cec/cecX/status`: show CEC adapter status information.

CEC & Hotplug Detect

- The CEC Physical Address of a source is set in the EDID of the sink. EDIDs can only be read by a source if the sink pulls the HDMI Hotplug Detect pin high. So no HPD, no CEC and no CEC, no way to wake up the sink via a CEC message.
- However, some displays turn off the HPD when in standby, but CEC is still enabled.
- CEC 2.0 allows for this in the small (*very* small) print of the spec.
- So the CEC framework can send a CEC wake up message to the TV even when there is no physical address. This may or may not work, there is no way to tell. Not all CEC hardware implementations can do this! See `CEC_CAP_NEEDS_HPD` capability.
- Even worse: some displays only wake up if this message is the first message they see. i.e. a poll message followed by a wake up message might fail.
- Also observed: switching inputs on a display (e.g. from HDMI 1 to 2) can cause the HPD to go down, then up again. The framework will disable CEC when it goes low, and reclaim the logical addresses when it goes up again. Any CEC application software has to be able to handle this.

CEC Utilities

- cec-ctl supports all CEC messages (autogenerated code) and is a quick way of interactively configuring a CEC adapter and sending, receiving and monitoring CEC messages.
- It also supports the Hospitality Profile Next Generation CEC extension.
  See http://www.htng.org/ for more information.
- It supports low-level CEC analysis (`--monitor-pin` option). Only available with sun4i and cec-gpio drivers.
- cec-follower emulates the high-level behavior of a CEC device.
- cec-compliance tests a remote CEC device whether it is CEC compliance or not. The main focus has been on features that Cisco needs, other features are only superficially tested. Help would be very welcome.

Current Status for kernel 4.14

- After two years of on-and-off development the CEC framework was merged in kernel 4.8 in drivers/staging and moved to drivers/media in 4.10.
- Supported USB CEC dongles: the popular Pulse-Eight USB CEC adapter and the RainShadow Tech adapter.
- DRM CEC support: Samsung Exynos 4 + 5, STIH4xx, stm32, Raspberry Pi, Synopsis dw-hdmi CEC IP, amlogic AO-CEC, Allwinner A10.
- V4L2 CEC support: adv7604, adv7842, adv7511, vivid (CEC emulation).
- Passed official certified CEC 1.4 and 2.0 compliance tests (thanks to Jose Abreu from Synopsis).
- Linux is the only OS that has built-in CEC support!

Work-in-Progress

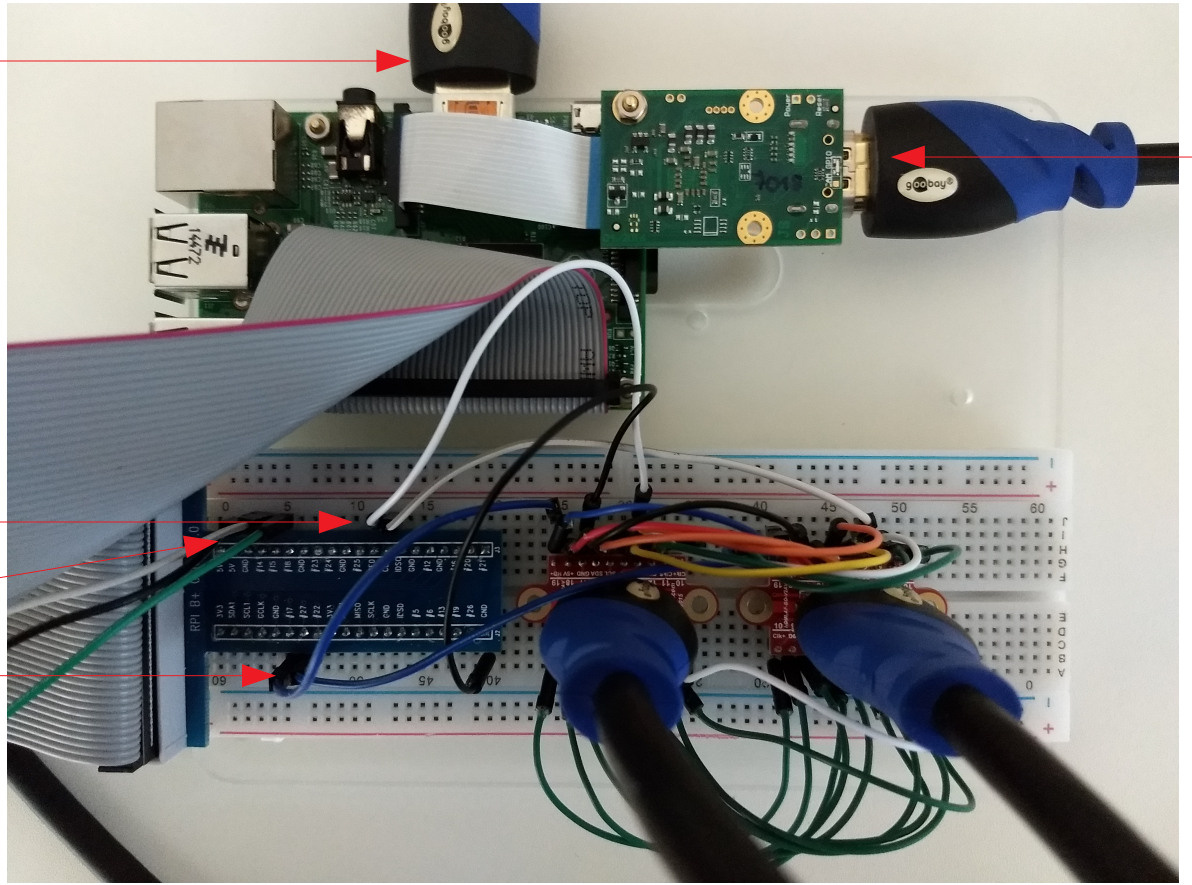
- DRM drivers: omap4, adv7511/adv7533 (Qualcomm Dragonboard), Tegra, DisplayPort CEC-Tunneling-over-AUX.
- V4L2 drivers: tc358743 (merged for 4.15).
- GPIO driver: cec-gpio (merged for 4.15).

CEC To Do

- Implement 'wake-on-CEC' feature.
- Improve cec-compliance to increase the test coverage of the CEC API (patches are welcome!).
- Error injection using low-level CEC pin framework used in cec-gpio and sun4i.
- Improve low-level CEC pin analysis code in cec-ctl.
- Use the remote control framework to also send RC messages, not just receive.

Demo!

Demo: RPi + tc358743 + 2x cec-gpio



Resources

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- HDMI/CEC Specification:
  https://en.wikipedia.org/wiki/HDMI
- Git repository for the media subsystem:
  https://git.linuxtv.org/media_tree.git/
- Git repository for the media utilities:
  https://git.linuxtv.org/v4l-utils.git/
- Media documentation:
  https://www.linuxtv.org/downloads/v4l-dvb-apis-new/uapi/cec/cec-api.html
  https://www.linuxtv.org/downloads/v4l-dvb-apis-new/kapi/cec-core.html
- CEC status information:
  https://hverkuil.home.xs4all.nl/cec-status.txt
- Pulse-Eight libcec patch adding support for linux CEC framework (Jonas Karlman):
  https://github.com/Pulse-Eight/libcec/pull/380
- My email: hverkuil@xs4all.nl

Questions?