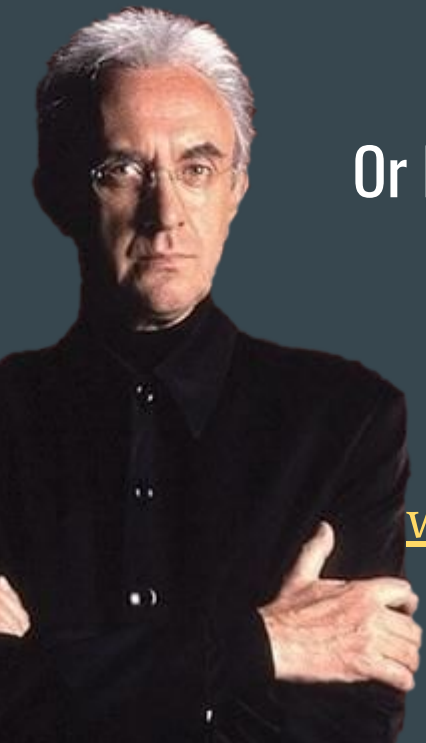


Being Elliot Carver

Or how to run a cable TV network in your living room

•••

Phil Pemberton
EMF, May 2024
www.philpem.me.uk / philpem@philpem.me.uk

A bit about me

- Software engineer, embedded systems
- Hobbyist maker - electronics, radio, firmware, metalwork...
- Licensed amateur radio operator (73's de M0OFX))
- Retro tech enthusiast and reverse-engineer
  - HackTV, NABU PC cable modem, Datatrak radio navigation
- Not a James Bond villain in disguise.

YOU ARE ENTERING
THE ANALOG TV SECTOR

DVB & MPEG IST VERBOTEN!

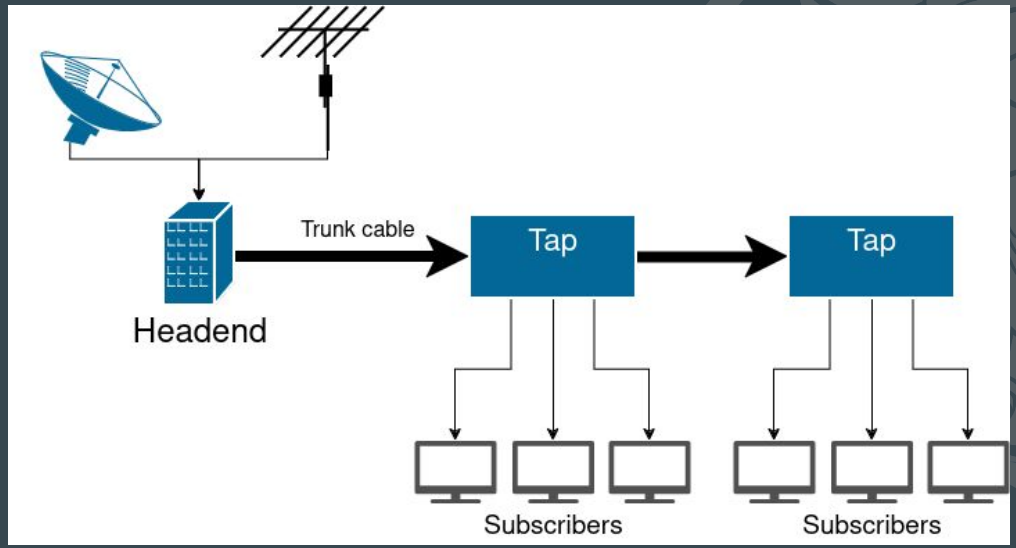
ENTSPANNEN UND FERNSEHEN

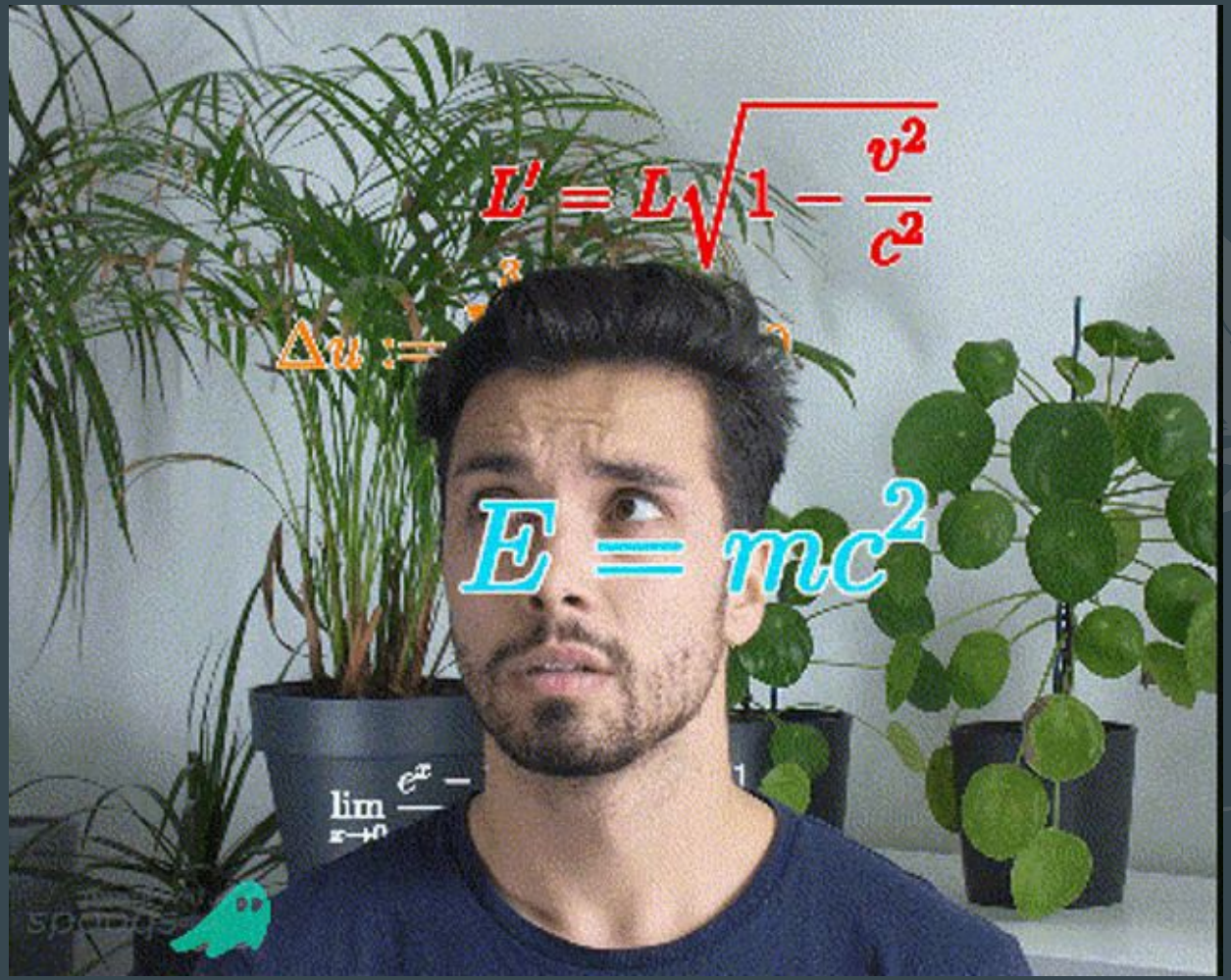
What is cable TV?

- Started as radio and TV relay services: *Community Antenna TV* or *Rediffusion*
  - Poor signal an issue in valleys around hills and mountains
  - Fix: Put the antenna on a hill, amplify the received signal, retransmit it over cable
- Happy coincidence: reduced cost of entry for new services
  - RF: New transmitter + licenses (£millions) vs. ~£1000 for another modulator
- Scalable infrastructure
  - ~500 MHz bandwidth, 8 MHz/channel => space for 60 channels! Telephone! Data!
- Led to an explosion in local and large-scale programming
  - Coverage of local news and events (e.g. Swindon Cable's "Swindon Channel")
  - HBO, Nickelodeon, TNT, MTV, ... with their own in-house productions
  - Many well-known "classic" shows are from the "Golden Age of Cable"
    - ER, Seinfeld, X-Files, Quantum Leap, The Sopranos, Breaking Bad, Game of Thrones ...

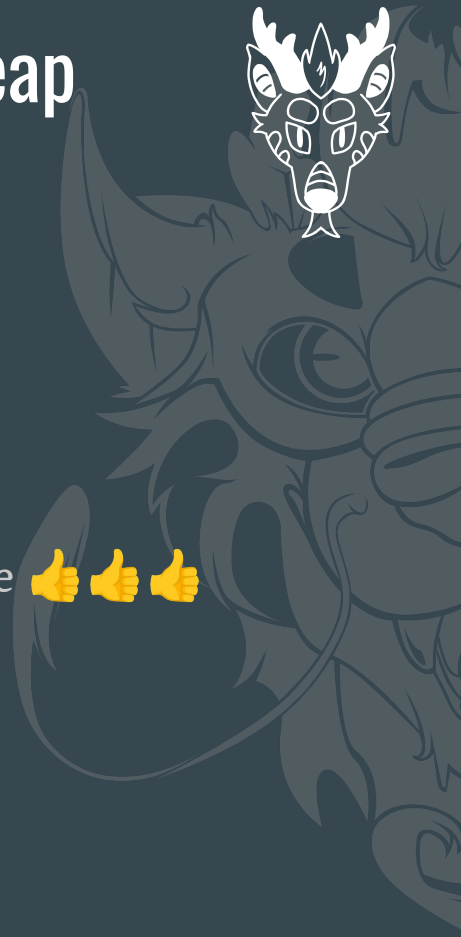
A typical commercial setup

- **Headend** receives satellite/antenna signals, retransmits them
  Adds locally-generated signals e.g. control data, local channels, DOCSIS
- **Trunk** cable (~13-25mm dia. ultra-low-loss co-ax) carries signals between Taps
- **Taps** tap off a fixed amount of the signal for subscribers (RF splitter)
- **Amplifiers** boost the trunk signal
  to cover longer distances
- **Node**: street cabinet with Fibre RX,
  Amplifiers and other H/W
- *Improvements over time*
  1980s: fibre-optic trunks
  1990s: DAVIC/DOCSIS internet




$L' = L\sqrt{1 - \frac{v^2}{c^2}}$
$\Delta u :=$
$E = mc^2$
$\lim_{x \to 0} \frac{e^x -$

Minimum viable product: getting started for cheap



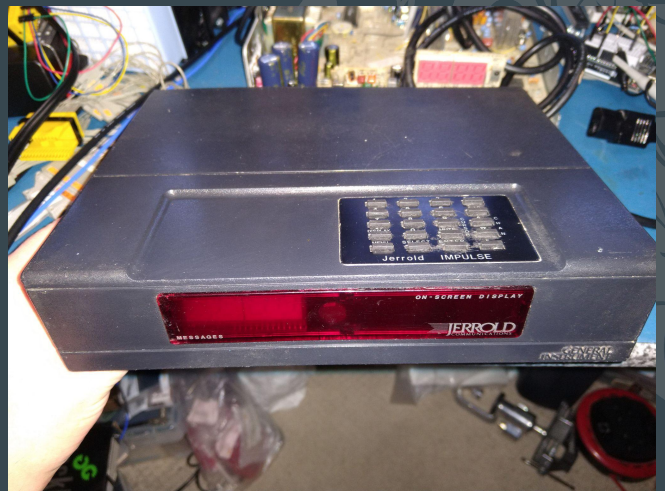
- Video source (DVD, Raspberry Pi, Laserdisc, VHS)
- Modulator
- Cables
  - Type-F threaded for RF connections.
    (Get an F-connector wrench to save your fingers.)
    - PPC Compression-type F-connectors and WF100 cable 👍👍👍
      Starter kit ~£20 (ebay)
  - Composite video usually BNC or RCA/Phono.
    (R-Pi will need TRRS and/or TRS adapters)
- TV with analog RF (antenna) input

No analog RF input on the TV?

- Some TVs don't have an analog RF tuner (= cost savings)
  - They usually still have analog video in (SCART or RCA jacks)
- Monitors only accept analog composite and/or S-video or component

- Easy way: old VHS VCR (it only has to power on) or DVD recorder

- Nerdy way: Make your own! (~£20)
  - Philips FQ1216ME
  - 5V and I2C in, composite video out
  - Arduino or similar for control
- Congratulations, you just build a simple cable box!



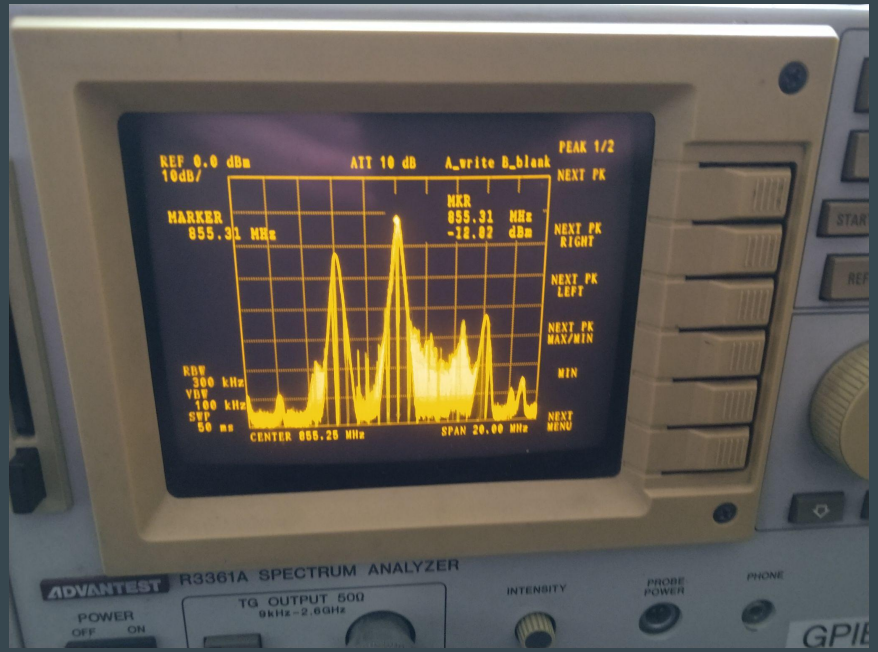
Generating video

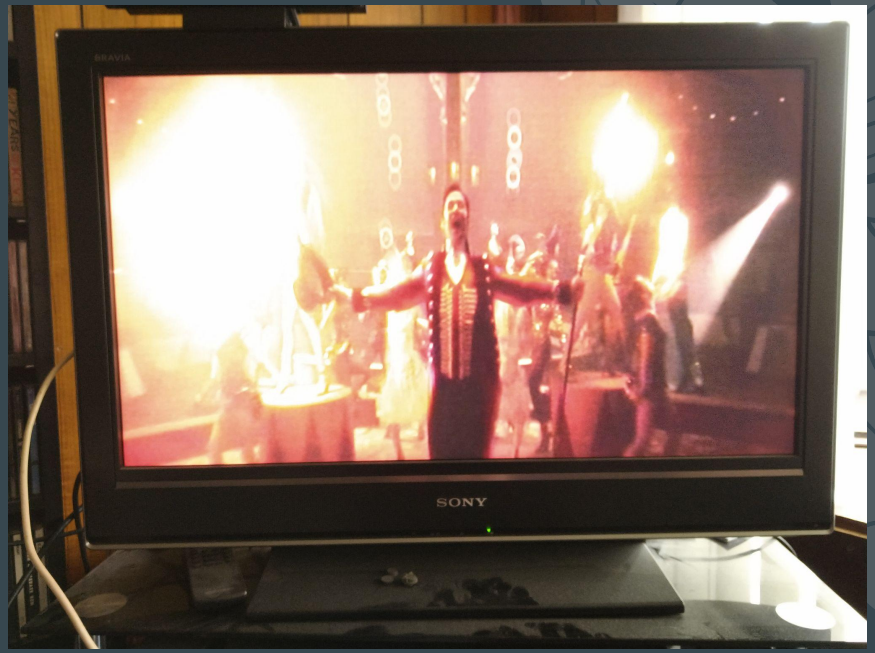
- Spare Raspberry Pi
  - Analog and HDMI on all models - config.txt allows a lot of configuration
    - Zero series and Pi 5 may need some soldering
    - 3B and earlier need a TRRS cable
- Spare PC
  - Usually only HDMI/DVI out: may need converters
  - More storage = better for big-dog playout
- Software
  - Lazy option: VLC/FFMPEG and a directory of videos
  - Comfy Channel
    - https://github.com/mvarhola/comfy-channel/
    - Handles scheduling of content, bumps (adverts) and “up next” screens

Modulation: from three wires to one

- HDM69 RF modulator (£35 ebay, less on Aliexpress)
- HDMI and Composite in
  - Set to HDMI with no signal -> colour bar test pattern
  - Stereo audio inputs but output is mono (no NICAM or A2 stereo)
- RF in-out loop-through: no need for a combiner
  - Has RF level and modulation adjustments for multi-channel setups
- Set for PAL-I, 8MHz, UHF C21-69
  - www.ukfree.tv will tell you which C-slots are free
- AM modulation (video): no VSB filter
  - Signal is 2x wider than standard on the negative end
  - Usually interferes with the lower audio carrier
  - FM “Capture effect” means TV locks onto the strongest
  - Space channels at least 16MHz apart

MVP: A-OK


REF 0.0 dBm
10dB/
ATT 10 dB
A_write B_blank
PEAK 1/2
NEXT PK
MARKER
855.31 MHz
MKR
855.31 MHz
-18.87 dBm
NEXT PK RIGHT
NEXT PK LEFT
NEXT PK MAX/MIN
MIN
NEXT MENU
RBW 300 kHz
VBW 100 kHz
SWP 50 ms
CENTER 855.25 MHz
SPAN 20.00 MHz
ADVANTEST R3361A SPECTRUM ANALYZER
POWER
OFF ON
TG OUTPUT 50Ω
9kHz-2.6GHz
INTENSITY
PROBE POWER
PHONE
GPIB


BRAVIA
SONY

Going from a channel to a network

- More channels! Just add more sources and modulators
  - RF splitters can be used in reverse as combiners
  - Some modulators can be looped through instead (no splitter needed)
- More outputs!
  - Amplified variable-gain splitter makes a usable low-cost launch amplifier
- Keep an eye on RF levels!
  - Channels should have reasonably consistent RF levels on the cable
    - Measure with channel-selective level meter

      ~£50-100 (new RY-S110D, used Technetix TE-1250)

      ~£300 (used Promax Prolink or TV Explorer)
    - Aim for ~75dBuV for a TV, or ~5-10dBmV for a cable box

Cool, what next?

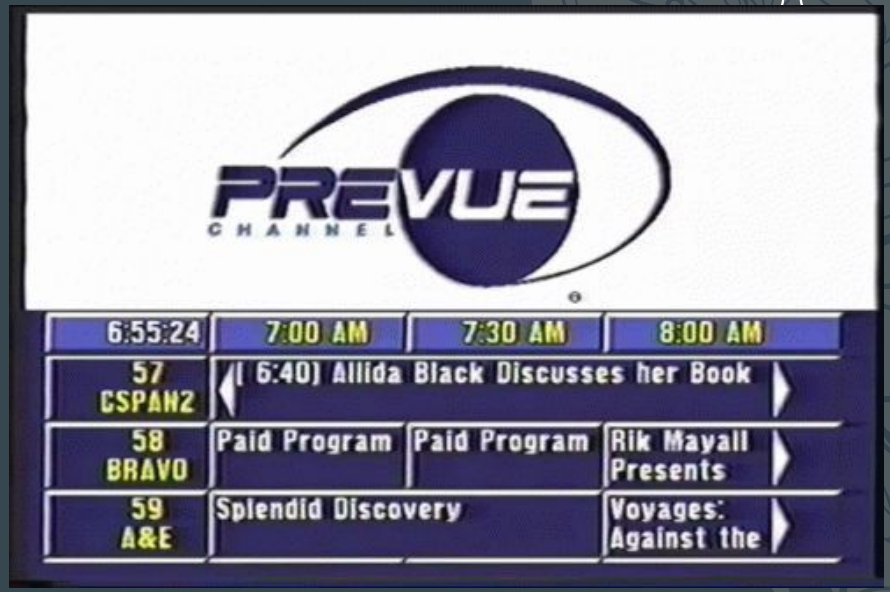
- We have our favourite movies and shows on TV and defeated choice paralysis!
- Now what?
  - VBI services: Teletext
  - Better sound: NICAM
  - Programme guide channel
  - Weather channel
  - Try to take over the world!

Teletext: data in the vertical blank

- This is analog only (doesn't work on HDMI) and requires a Raspberry Pi.
- Uses two software packages:
  - VBIT2: https://github.com/peterkvt80/vbit2 (turns a directory of pages into a stream)
  - Raspi-Teletext: https://github.com/ali1234/raspi-teletext (puts the stream into the video)
- VBI insertion is done with the Pi's video output -> no HATs needed!
- Installation instructions on the VBIT2 Wiki
  - Just run one script to get started!
- Teletext page editors: https://zxnet.co.uk/teletext/editor/ and https://edit.tf/
- Friendly community -
  - Facebook: https://www.facebook.com/groups/TeletextGroup/
  - Discord: https://discord.gg/JfytfS3xmg

Pre-EPG programme guides: Prevue Guide

- Problem: we don't know what's on
- No OSD - we're not even using a cable box
  - GI CFT2200 was one of the first with EPG ... but requires special headend hardware
- Solution: run Prevue Guide on an Amiga 1200 I just happen to have lying around... Genlock converts RGB to PAL
- If you don't have an Amiga: use UAE emulator or Prevue Simulator and a Raspberry Pi

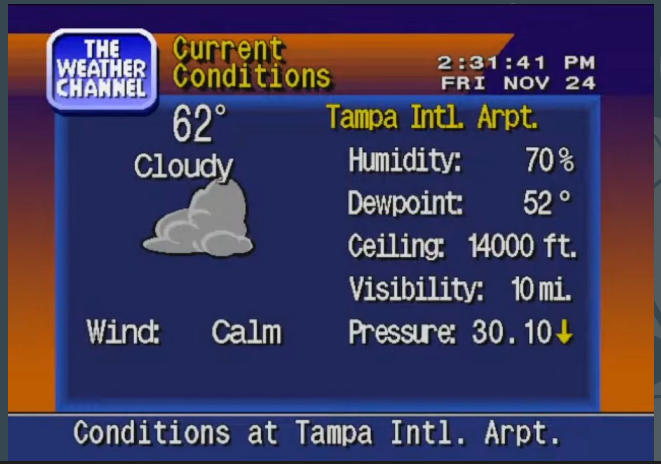


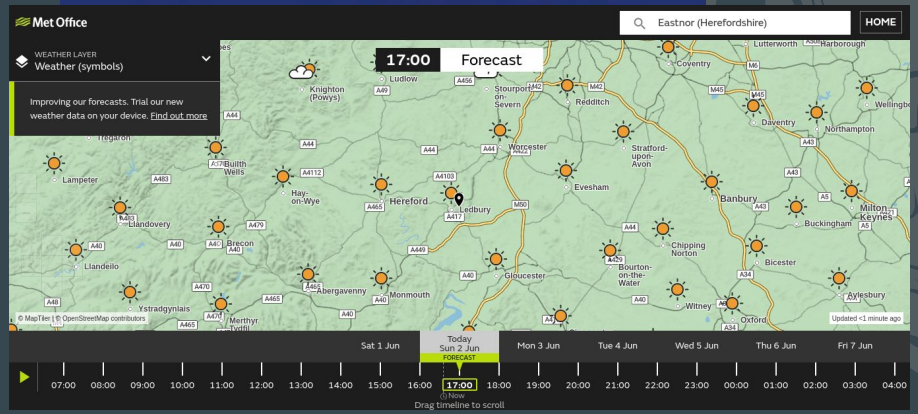
See:

- https://prevueguide.com
- https://park-city.club/~frix/prevue/

Information services: Weather

- *Why should I have to look out the window? I have a TV!*
- WeatherStar 4000 simulator (https://www.taiganet.com/) is cool
  ... but only works for US cities.
- UK option: Met Office
  - Load website into an iframe
  - Custom JS to switch between player, maps, forecast.
  - Custom CSS to tidy things up for TV
  - Bonus: the ad banner disappears auto-magically on small screens!





Wild cards: the NABU PC and cable Adaptor

- NABU PCs and CATV Adaptors were found in a warehouse last year and sold on eBay
- Retrocomputing enthusiasts bought them
- Cable adaptor reverse-engineered this year
  - Jared Boone, Youtube: “The 40 year old cable modem” (RF)
  - Me: Github, packet engine MCU ROM dump, reverse-engineered schematic
- Work ongoing, but will soon be able to use a SDR + Gnuradio to generate NABU headend “wheel” carousel

Image credit: revspace.nl, CC-BY-SA

Embiggen the thing: Reviving old cable boxes

Making a cable network

- We've made "cable TV" a TV can tune into. What about a cable box?
- Boxes expect an "out of band" downlink from the headend
  - Need a headend controller (Addressable Controller) to generate this
- Messages the box needs:
  - Date and time (optional but recommended)
  - "Timer Reset" command: resets the Disconnect timer
  - "Enable" command: activates the box, if it's deactivated
  - System site code or password: set this to an arbitrary value and keep repeating it.
    - Used to prevent boxes from being moved between providers without authorisation
  - Input and output frequency maps (RF channel start, logical number, spacing)
  - Logical channel map and names (channel 1 is RF channel 31 aka "BBC1", 3 is 53 aka "ITV", etc)

General Instrument ACC-4000 Addressable Controller

- Manuals turned up on SegaRetro.org's "Sega Channel" page.
- I posted on VCFED in 2023 looking for the software and hardware.
- Someone had one to sell (in part)!
  - DEC ApplicationDEC 400xp server, 486DX4-100, Interactive Unix 3.2
  - Software was VERY old (version 6.3, last release was 12.0)
    - No support for CFT-2200 Smart boxes, but works OK with everything else
  - Seller sent Ghost images of the three hard drives and sold me the GI-specific hardware
    - And FedEx lost the hardware for two weeks...!

Overengineering, Jerrold style: the ANIC

- Lets the PC communicate with the headend equipment and cable boxes
- ANIC is an embedded 286 PC-AT
  - 1MB RAM (30 pin SIMMs), no VGA, serial port (not used)
  - Custom data interface built around a Xilinx FPGA
  - Data protocol is packetised, RS232 formatted, then Manchester biphase coded
- Talks to the PC over SCSI ... but the ANIC is the Initiator!
- PC or ANIC can organise the packet stream
  - Lists: same packet sent to a list of boxes. Used for background updates.
  - Punch: send a packet *now*. Used for instant changes (e.g. customer service calls -> Box Init/Refresh)
  - Poll: like a punch, but has return data. Used for opinion polling and system integrity checks.
    - “Box 555-1234, upload all unsent pay-per-view purchase records.”
    - “Scrambler 867-5309, what is your status?”

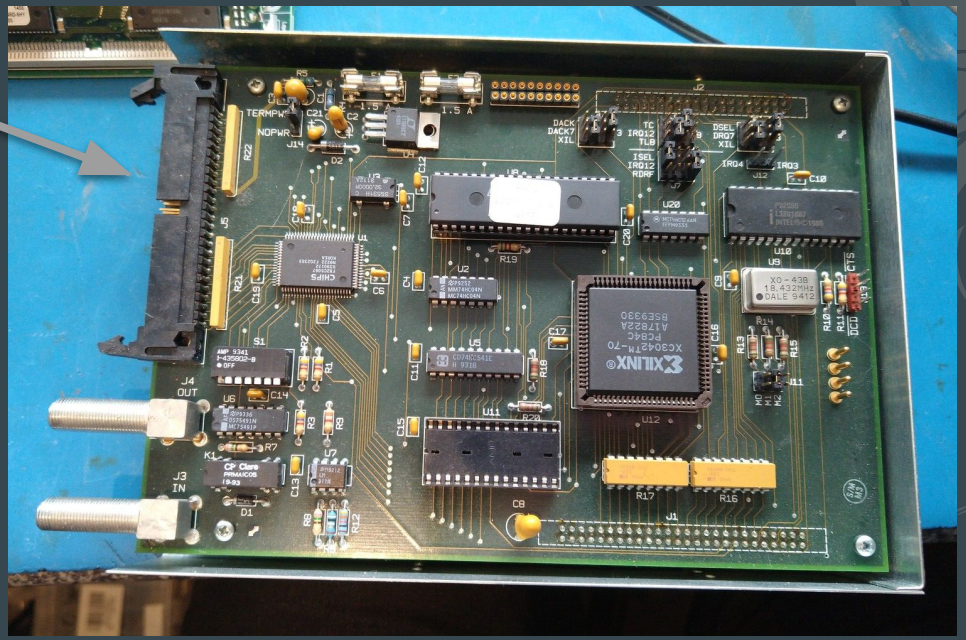
The ANIC in pictures

SCSI

(Molex 5V/12V power underneath)

Data Out

Data In

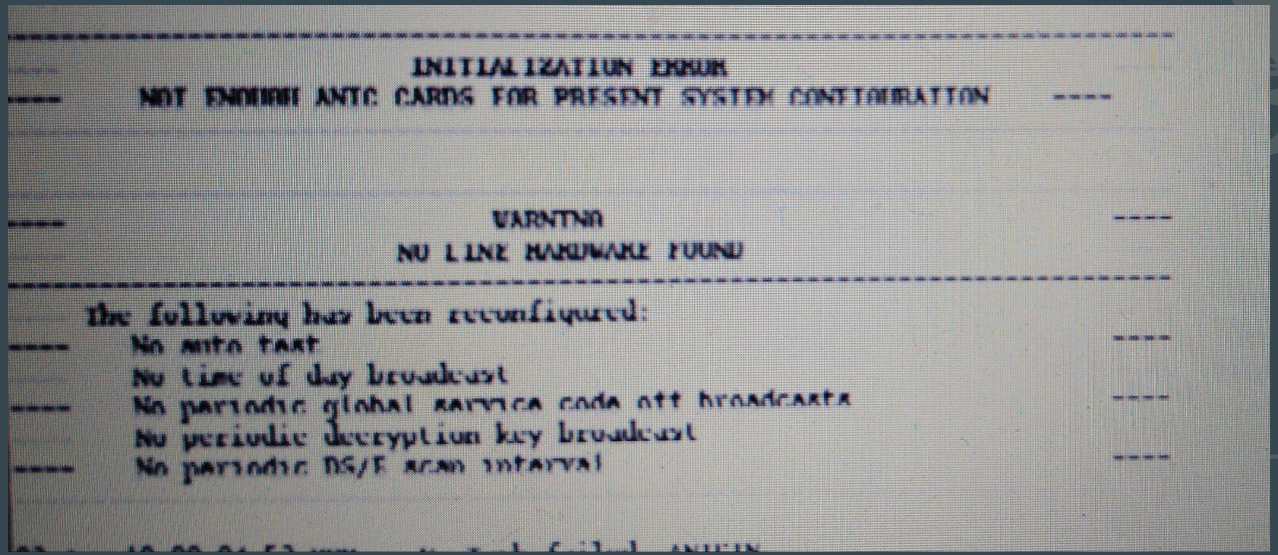


Building a new Addressable Controller

- K6-II/400 PC rescued from garage and kitted out
  - New Dallas clock module battery (Dremel hack) -> PC wouldn't boot with bad battery!
  - Western Digital PVGA1024 WD90C30 graphics card
  - Adaptec AHA-1540 ISA SCSI for main disks (3x 500MB, emulated by BlueSCSI)
  - Buslogic SCSI controller for the ANIC
- Upgraded Interactive Unix to v4.1.1 (last release) for better hardware support
  - Disabled drivers for removed hardware (port concentrator and APC UPS)
  - Fixed issues with crontabs not running (and other brokenness)
- Upgraded the hardware
  - Adaptec AHA-2940UW SCSI controller for boot disks (3 off, on BlueSCSI V2) => faster boot
  - Trident TVGA8900C graphics => non-interlaced 1024x768 16-colour graphics
  - Brainboxes quad RS232-POS serial port card (terminals and Wirelink)
  - Intel PRO/100 Ethernet card (3C509B had issues on IUNIX)

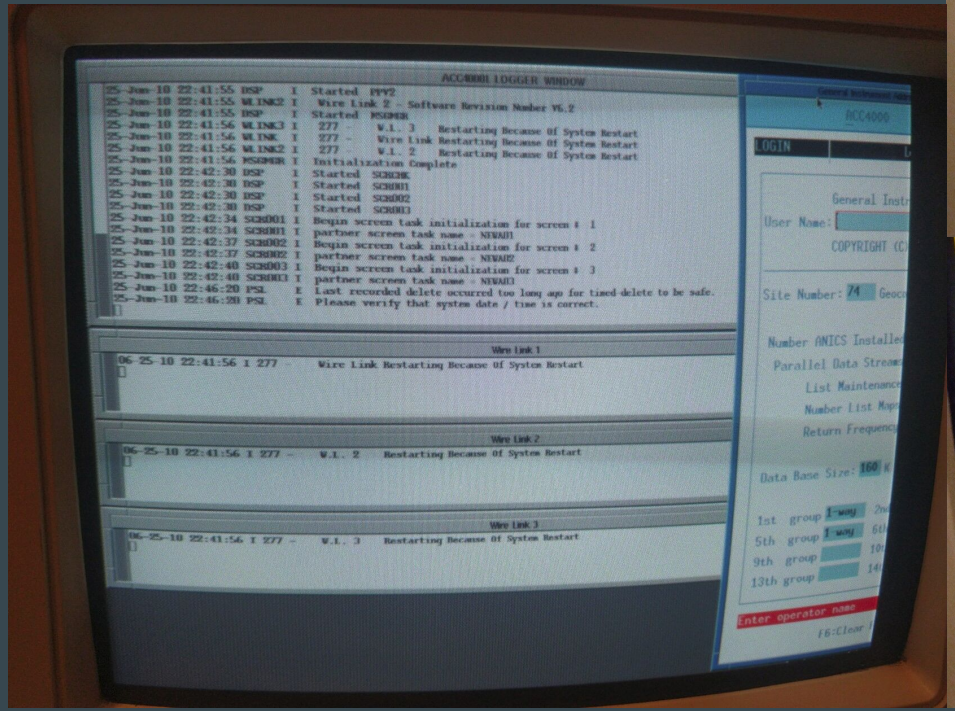
A small problem

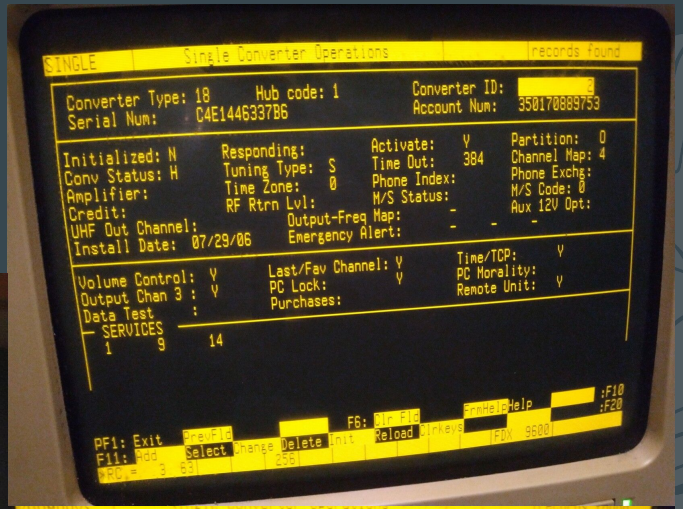
The ANIC had been damaged by a leaking Varta CMOS battery.
This broke the RAM address decoder...

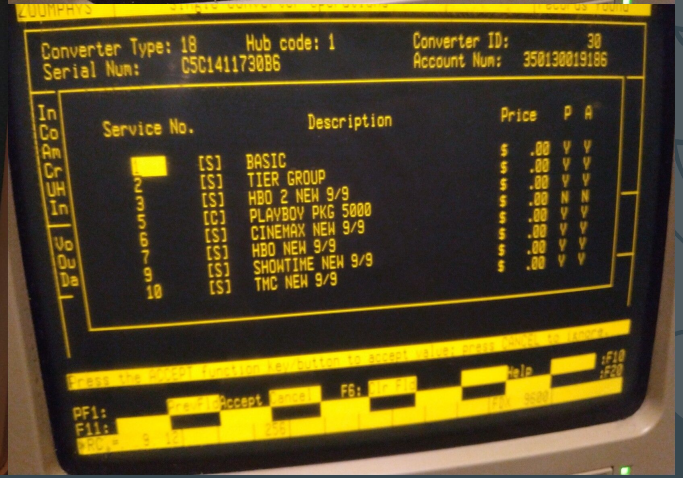


It’s alive!

After repairing the damaged ANIC:





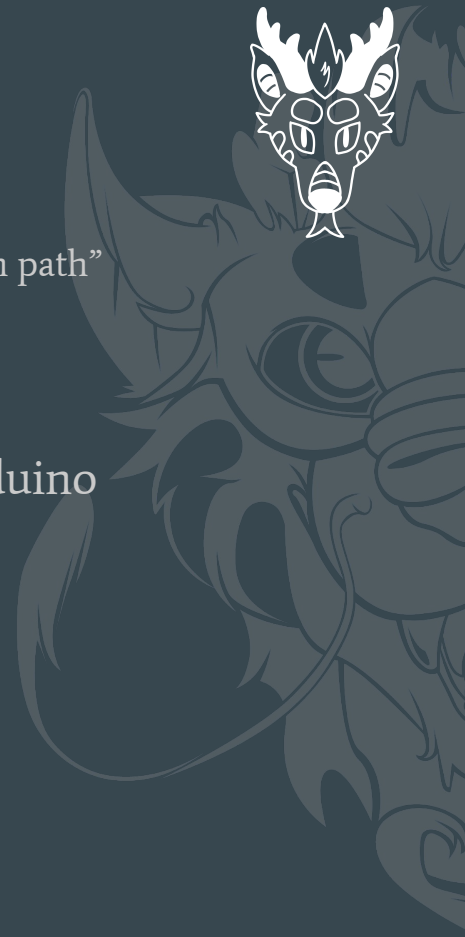


Generating the out-of-band channel

- Usually generated by a “Data Commander”
  - Generates OOB downlink at ~100MHz
  - Receives return channel at ~8-10MHz
  - *Can’t find one for love nor money.*
- The RF modulation is just FM, though
- Can we just use an RF signal generator?
- Answer: Yes.
  - I used a Marconi 2022E in FM mode
  - Used a TV/SAT splitter to combine the RF-out with the modulated video signals.

Next steps

- Boxes can send data back using a “Starvue” module
  - Modulates data in FM on a 8-10MHz carrier: the “return channel” or “return path”
  - Need to build a receiver: nothing commercially-available goes this low
  - May be able to sniff the data off the Starvue module connector.
    - Only six out of eleven wires are used
- Reverse-engineer the headend and rebuild it on a Pi Pico or Arduino
  - Smaller, lower power
  - Lets other people build one and set up their own headend

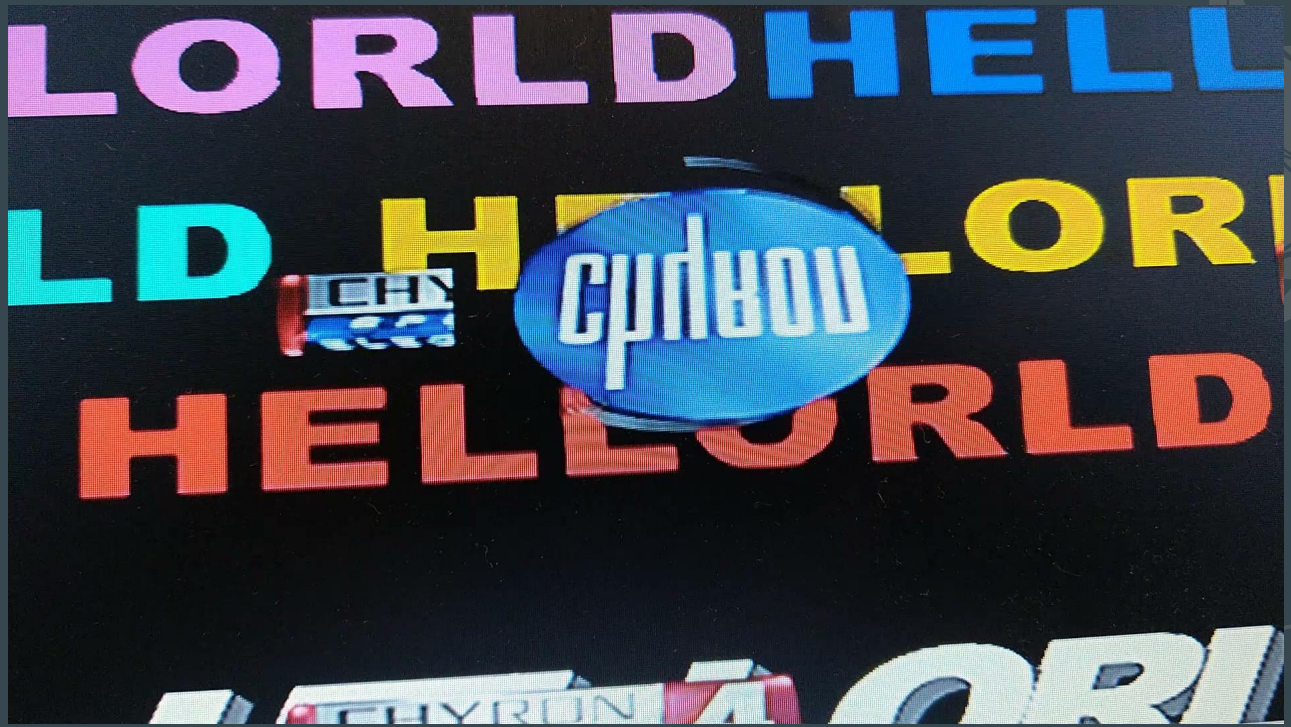


Going further: reuse and recycle

Fake news: Chyrons and crawlers

- A friend got an Aston Green and I wanted one. Nobody was selling one :(
- Found a Chyron Analog Lantern 64 card (pcCODI) on ebay US for £50
  - Turns out this is a PC-based character and graphics overlay card, similar to the Aston
  - Philips TriMedia processor, 64MB RAM, GPIO port, audio port
  - Digital Lantern is the same but has Digital SDI video in/out
- I put it in a PC.
  - Drivers, SDK and Lyric software were on Chyron's FTP site
  - SDK very easy to use: load graphics and fonts, send drawing commands (text).
  - Can use Chyron's Lyric software to set up 'pages' which can be loaded
- Now I can overlay news crawlers and sports scoreboards onto live video!

Chyron demo



Making life easier: matrix switch

- Matrix switch, aka Crosspoint switch.
- Any input to any output - or several.
- Wire everything into the Crosspoint, control it with software.
  -> No need to re-wire!
- Makers: Comm-tec, Kramer, Extron
- Aim for something with Ethernet or RS232 control

What I'm doing next

- All-in-one headend
  - RP2040 controller, JSON interface
  - 88-122MHz FSK modulator = headend commands (OOB)
    (AD9834 DDS + Si5351A LO + mixer)
  - 8-10MHz FSK demodulator = return path
    (FSK receiver from broken cable box + Si5351A?)
- Video scrambling
  - Get this working - then add support to HackTV
- ... Cable TV at EMF 2026?

Q&A

- https://www.philpem.me.uk/ (web)
- https://digipres.club/@philpem (fedi)
- philpem@philpem.me.uk
- DECT: 3699 (FOX9)
- Outside the Robot Arms for a little while