



## TUTORIAL 1 ... part 1

# Not your Father's AM Car Radio

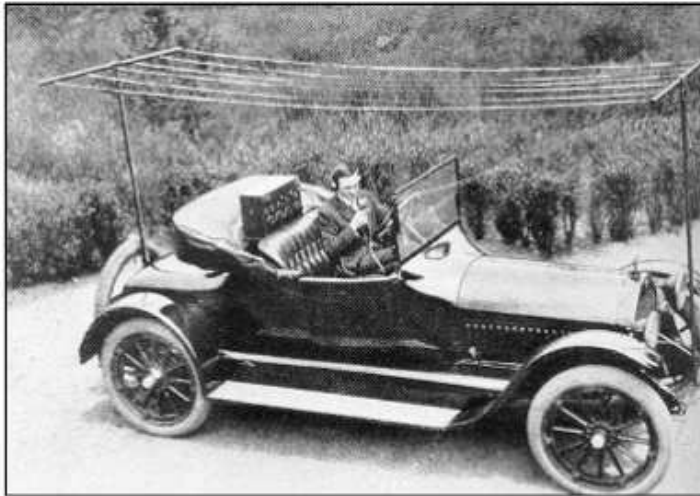
*Characterizing the Audio Performance of Today's  
Multi-layered Infotainment Systems*

**Jayant Datta** and Dan Foley

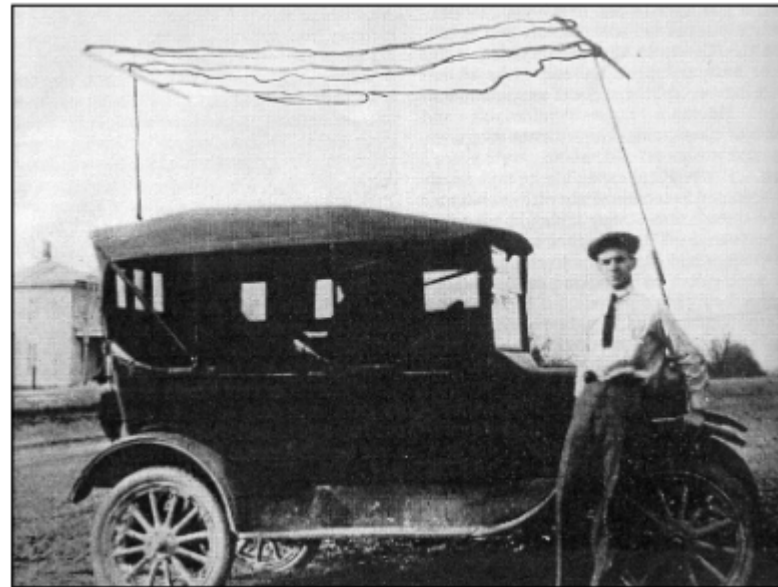
08 Sep 2017

- **Automotive Audio :: Past to Present :: Background [Jayant Datta]**
  - Evolution of Audio Solutions
  - Signal Chain
  - Testing
  
- **Audio Signal Path :: In-depth Considerations [Dan Foley]**
  - Evaluation Boards | Acoustic | Analog | Bluetooth | PDM | I2S | Busses
  - Gotchas
  - Examples
  
- **Questions**

## 1920s and before



Radio manufacturer Alfred H. Grebe installed an amateur radio station in his vehicle in 1919—even before entertainment radio began. Notice the elaborate wire antenna stretched between the two masts.





An automobile with a loop aerial in front of the wind screen and a receiving set on the dashboard recently made its appearance in the streets of New York. Crowds gathered wherever it stopped and listened to the music of broadcasting stations. Mr. and Mrs. J. C. Davenport, owners of the car, were testing out their new radio set, known as the "Dashboard Special." They had just completed a forty-thousand mile tour and were about to leave on a second tour of indefinite duration. The upper picture shows the "Dashboard Special" in front of the Pennsylvania Station, New York City. The lower picture shows Mr. Davenport and the arrangement of his car's fine radio equipment.

Here is the  
**World's Lowest Priced  
QUALITY AUTOMOBILE**  
**\$525**  
FAIR, FINE, HIGH.  
PRICE SUBJECT TO CHANGE WITHOUT NOTICE

**CHEVROLET**

TRUCKS, ROADSTER OR  
LIGHT DELIVERY CAR  
BUILT ON A FLINT WAGON  
FULLY EQUIPPED

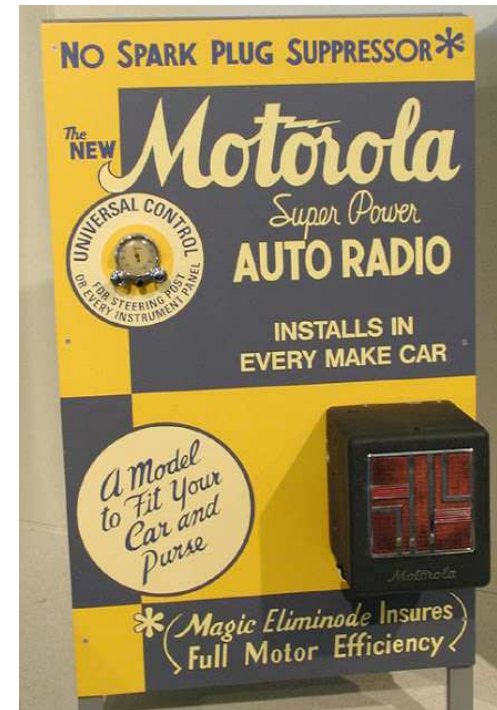
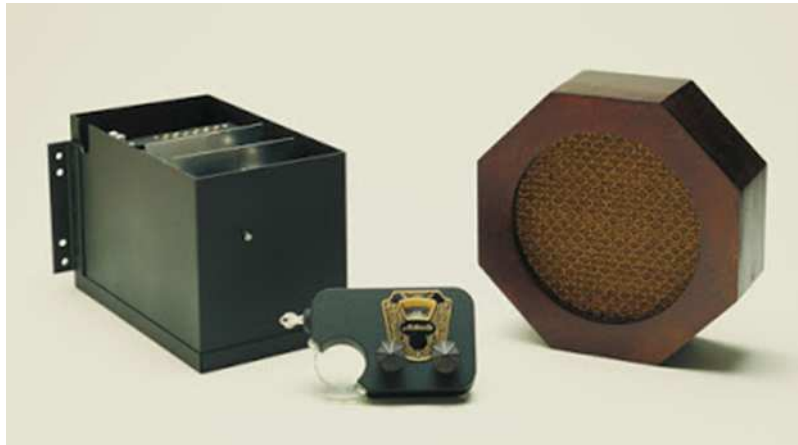
DESKINDER ADJUSTABLE  
PASSENGER COUPES AND  
P. D. R. FULLY, HIGH  
FULLY EQUIPPED

FOR ECONOMICAL TRANSPORTATION

Success To All

1930s

First commercially successful car radio | Debate over radios





1950s

AM dominates | FM receiver | Record player



**NOW... another exclusive from Chrysler Corporation!**



### **HIGHWAY HI-FI PHONOGRAPH** ... provides the music you want wherever you go

It's another Chrysler Corporation first!

Highway Hi-Fi gives you the finest tone reproduction—even on rough roads. A special counter-balanced pick-up arm and shock-proof case insure unsurpassed playing. Conveniently located under the instrument panel . . . the Highway Hi-Fi record player slides in and out easily

and can be operated without taking your eyes off the road.

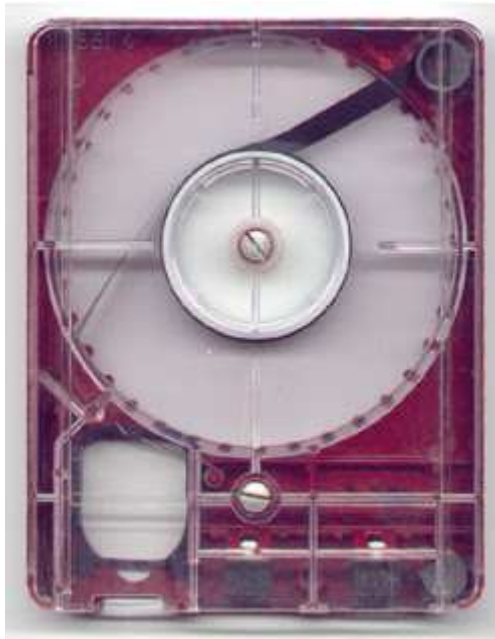
The 16-2/3 rpm records play from 45 minutes to one hour on each side and are available in a wide variety of musical and dramatic classics, popular favorites, stories for children, famous Broadway musicals . . . in short, a complete modern record library on wheels.

Highway Hi-Fi is just one of many dramatic new and exclusive features that are available on all the cars of the FORWARD LOOK™. There's new magical Pushbutton PowerLite . . . new LifeGuard door latches . . . new, surer hydraulic brakes . . . all-new FLIGHT-SWEEP styling. See all of these new features at your dealer's now!

**CHRYSLER CORPORATION > THE FORWARD LOOK**  
PLYMOUTH • DODGE • DE SOTO • CHRYSLER • IMPERIAL

1960s

Car stereo born | 4-track | 8-track | Play your own music



1970s

8-tracks faded | Cassettes introduced | Customized playlist





## 1980s + 1990s

CDs | Coexists with cassettes | CDs become dominant in 1990s



1990s + 2000s

CD-RWs, mp3 | Video head units | USB | Bluetooth | HDD-based



CAR  
STEREO

6.1"  
LCD

DVD  
PLAYER

Bluetooth

2000s –

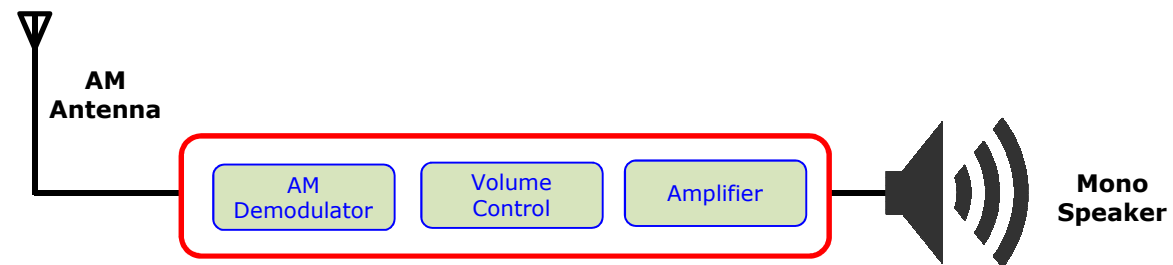
Satellite radio | Last OEM cassette | Streaming | Infotainment



# Automotive audio :: many duties

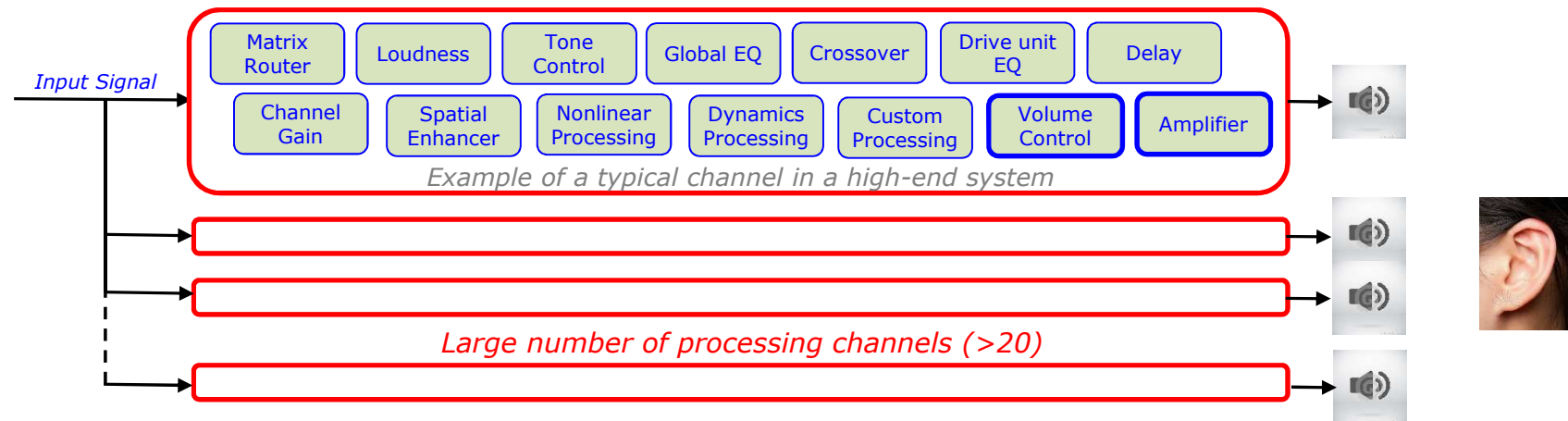
<b>Audio playback</b>	High-quality, (increasingly) high-resolution, sophisticated playback system
Warn driver	Chimes, alerts
Warn pedestrians	Sounds external to the vehicle
Reduce weight	ANC (use active signals to cancel various types of noise instead of using absorption/isolation material)
Enhance driving experience	Provide the impression of a powerful traditional engine by generating engine sound
Connectivity	Mobile office   social communication   expectation of excellent hands-free operation   streaming
Additional processing	Microphone arrays   beamforming   speech enhancement   natural language processing
Personal sound zones	<p>Access to multiple content ... audio is 2-way (system commands/conversations)</p> <p>Intelligibility important</p> <p>Personal sound zones vs Noise cancellation at Low frequencies vs High frequencies</p> <p>Rear-facing driver's seat</p> <p>Reduction of audio power requirements</p>

## Father's AM Car Radio





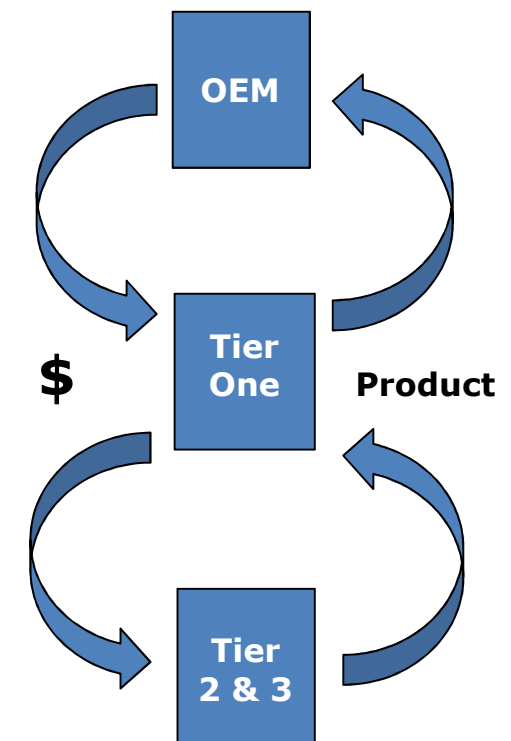
# Signal chain



- Some channels may be ganged together for certain functions
- Diagnosing issues can be very challenging
- **2-ch source → multiple processing channels → acoustically recombined for 2 sensors (ears)**
- End-to-end testing alone is inadequate

# Benefits of testing

- **Verify design and performance**
  - [Test designs and components in the lab](#) | verify integration of subassemblies | test performance in-vehicle
- **Avoid the blame game**
  - Problems in complex systems can lead to premature (often incorrect) conclusions
  - Solid verification tests legitimize solutions ... allowing one to stand one's ground
- **Reduce costs**
  - Reduce redesigns, recalls and returns; catch mistakes early, before they become expensive
- **Save time**
  - Use powerful [offline processing](#) and simulation testing tools
    - be more productive when prototype vehicle becomes available
  - Faults found early keep production running smoothly

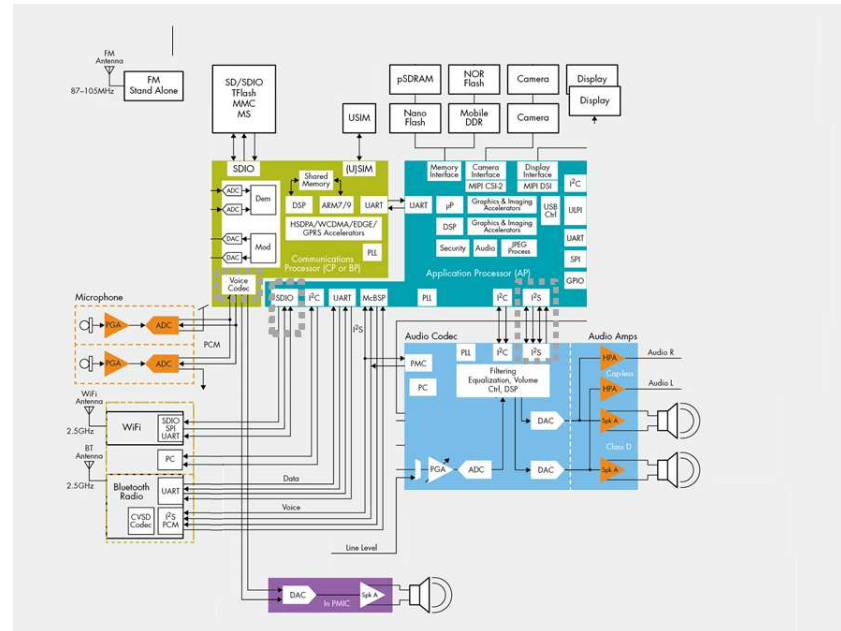
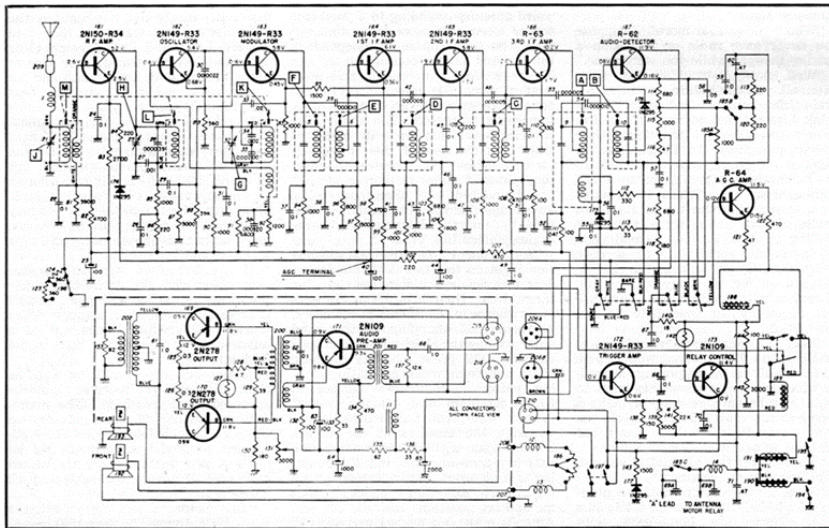


# Test in a methodical and diverse manner

- **End-to-end testing**
  - Total system test required to ensure overall performance
  - Maybe too late to determine where in the signal chain the problem may lie ... like [unscrambling an egg](#)
- **Modular testing of functional blocks | Testing the [signal path](#)**
  - Build up functional blocks gradually, testing each level of functionality
  - Signal source, signal processing blocks in isolation and combination, amplification, power supply, drive units
- **Using [multiple stimuli](#)**
  - In some cases, a single stimulus may be inadequate to uncover all issues
  - Different stimuli probe the design in a different manner – could elicit additional diagnostic information
- **Test, test, and retest**

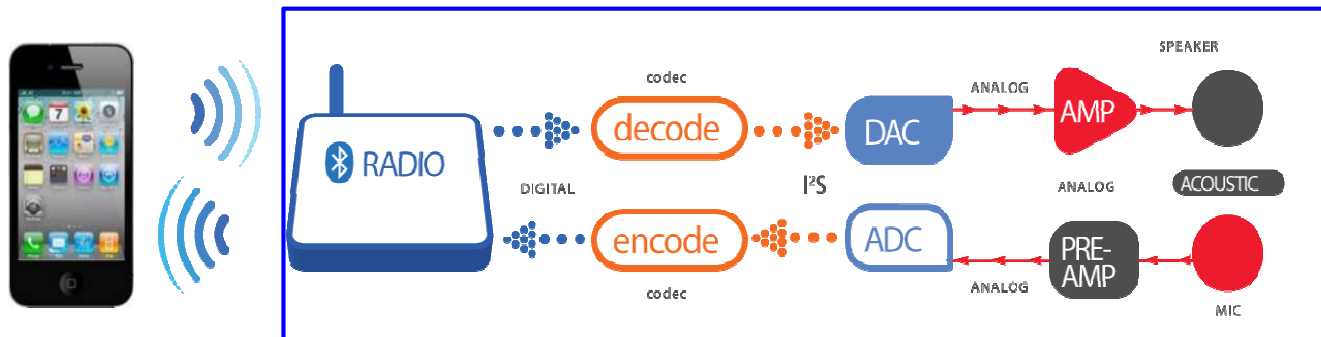
# Complexity :: 1957 vs 2000s

## First all-transistor auto radio | Today's functional block diagram



# Versatile testing platform

- When audio was analog, one could use an oscilloscope probe and follow the signal path ... look for signal degradation ... localize the problem area



- Use the same concept ... but adapted for the modern signal chain (versatile “oscilloscope”)
- Variety of audio interfaces required to test each step of the entire signal chain:
  - analog | digital | I2S | TDM | HDMI | PDM | Bluetooth, etc.
  - Test points needed to monitor/inject signals
  - Requires having adequate expertise/tools in a wide variety of areas
  - For example, codecs often get blamed for bad sound ... need to ensure input signal to codec is of high quality



# Interim Thoughts

- We have come a long way from the original car radios
- Extremely complex system, responsible for many things in addition to presenting audio signals to the occupants
- Sophisticated signal chain requires modular testing of functional blocks in a methodical manner
- Requires multiple domain expertise on the part of the designer, tester and the test equipment
- ... over to Dan ... let's dig into some of the details ...

# Acknowledgements

- **Thank you for your attention**
- **I would like to thank my AP colleagues**
  - Joe Begin
  - Dan Foley
- **I would like to thank my former THX colleague**
  - Laurie Fincham
- **References**
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## Appendix :: Audio Connectivity

### ANALOG OUTPUTS

2 channel  
8 channel

### ANALOG INPUTS

2 channel  
4 channel  
8 channel  
16 channel

### NOT SHOWN

AES/EBU SPDIF  
PERCEPTUAL TESTS  
FILE ANALYSIS  
ASIO  
ASIO-connected I/O  
MADI



### PDM

Direct I/O with modulation and decimation of PDM audio for testing of MEMS mics, with a wide range of oversampling rates.

### DIGITAL SERIAL

Direct connection at chip level. I2S and up to 16 channels of TDM supports left justified, right justified, DSP formats.

### HDMI + ARC

Measure Dolby/DTS audio and format on set-top boxes, home theater receivers, smartphones and Blu-ray Disc™.

### BLUETOOTH

Has built-in radio and support for A2DP (SBC and aptX®), mSBC, CVSD codecs, HFP, HSP AVRCP profiles