Engineering Design with Embedded Systems

Lecture 2: Sensors and Actuators in a Smartphone

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Plan

Today we'll look inside a Samsung Galaxy S, with pictures from:

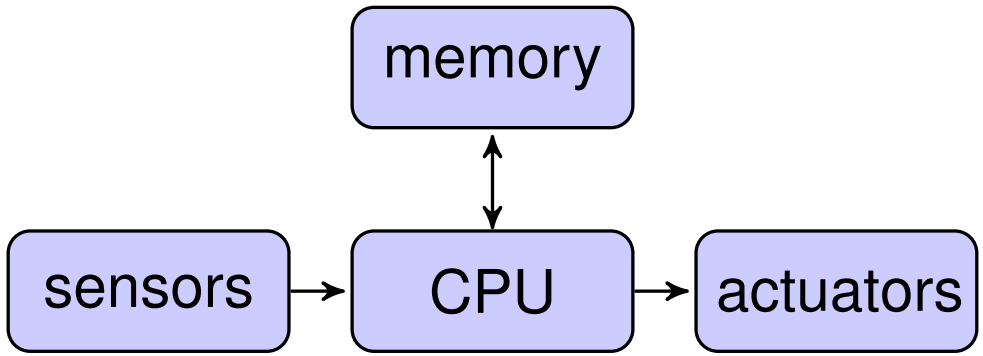
`http://www.ifixit.com/Teardown/Samsung+Galaxy+S+4G+Teardown/4977/1`

Thanks to `ifixit.com` for posting these pictures under the CC BY-NC-SA license.

Educational goal: be able to discuss sensors and actuators, plus embedded operating systems.

Sensors and Actuators

In particular, today we'll see how a typical phone integrates sensors and actuators, as typical for embedded systems.



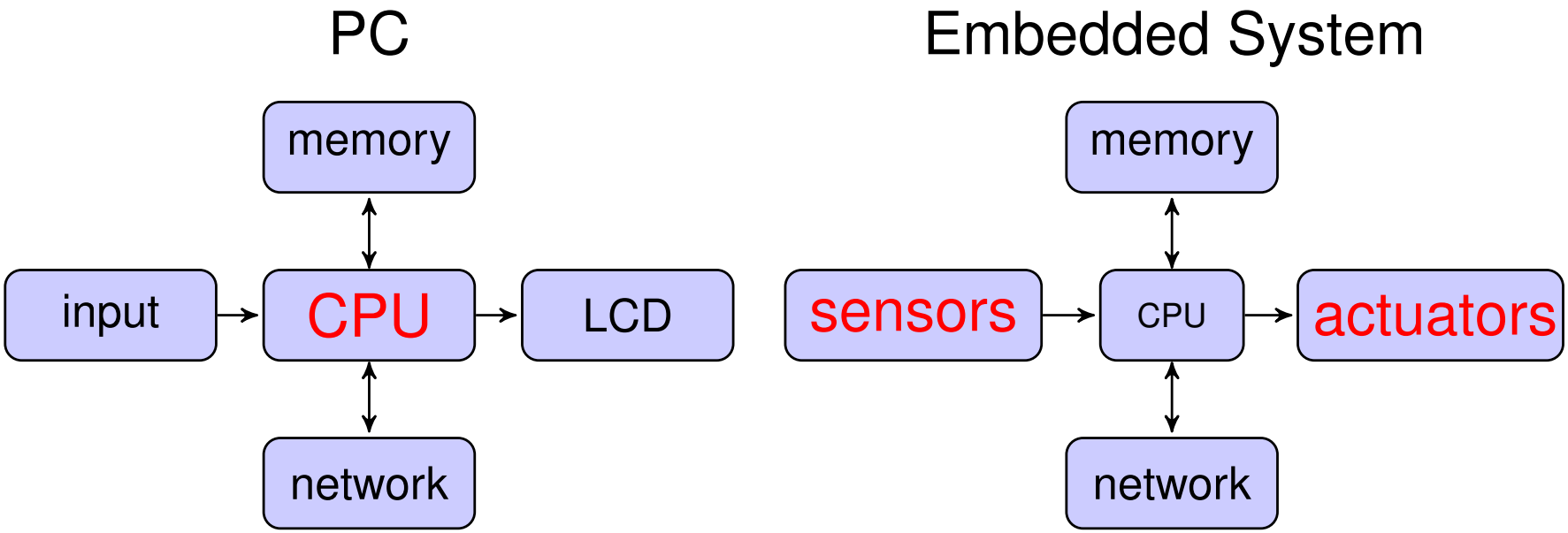
Specifications:

- 1GHz ARM "Hummingbird" processor
- 512MB RAM (plus 1GB storage & MicroSD slot)
- 480x800 Super AMOLED display
- 5.0MP and VGA cameras

What actuators can you see?

PCs vs Embedded Systems

Compare and contrast:



Opening the Phone

First Sensors and Actuators

Really Opening the Phone

This is as far as I'm willing to go with my phone. Thanks, Internet!

We're going to look at the components of the phone now.

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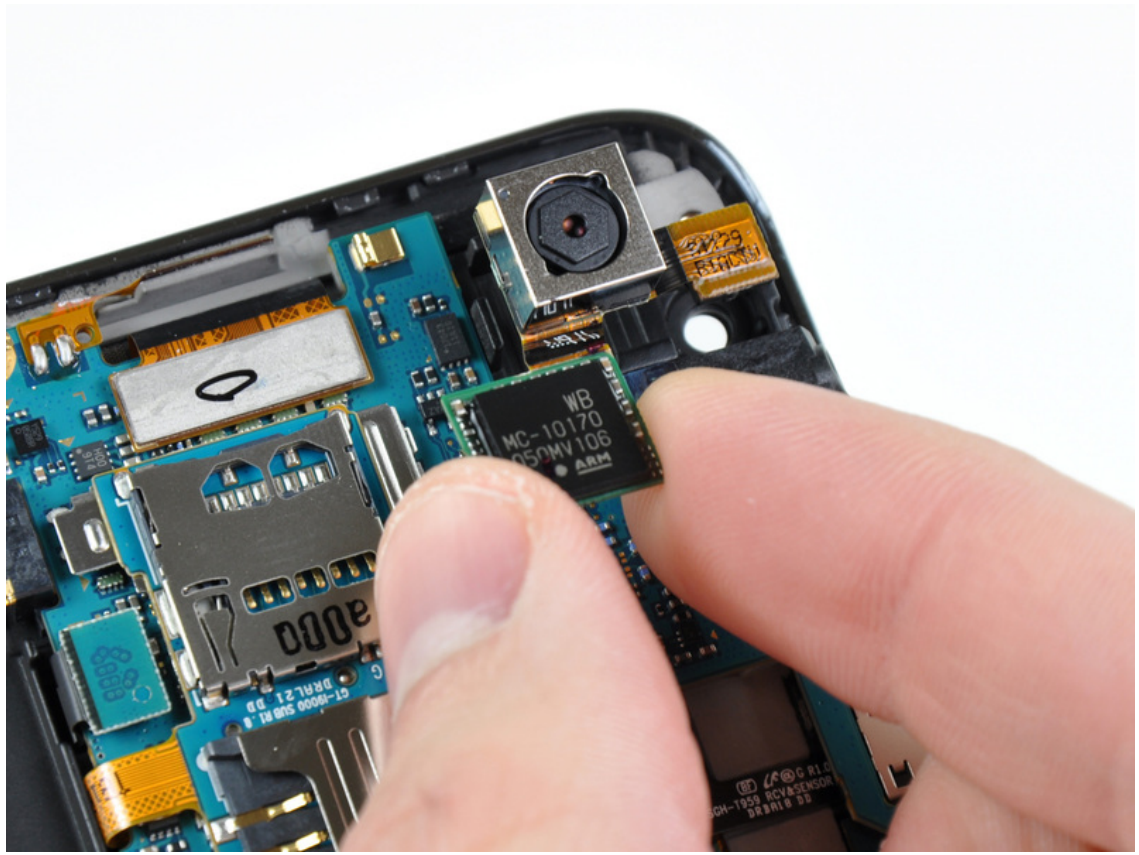
Phone Speaker

Speakers are definitely actuators; they move the air.

`http://www.howstuffworks.com/speaker.htm`

Cameras

Next up, we have some sensors.



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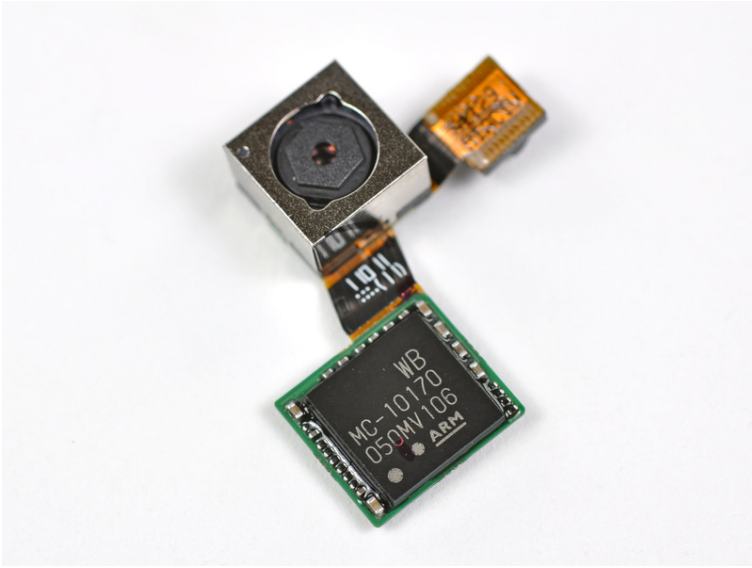
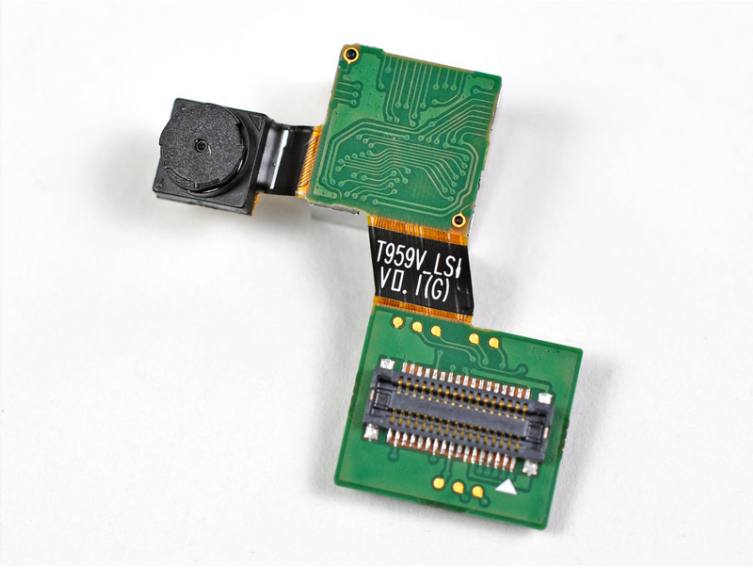
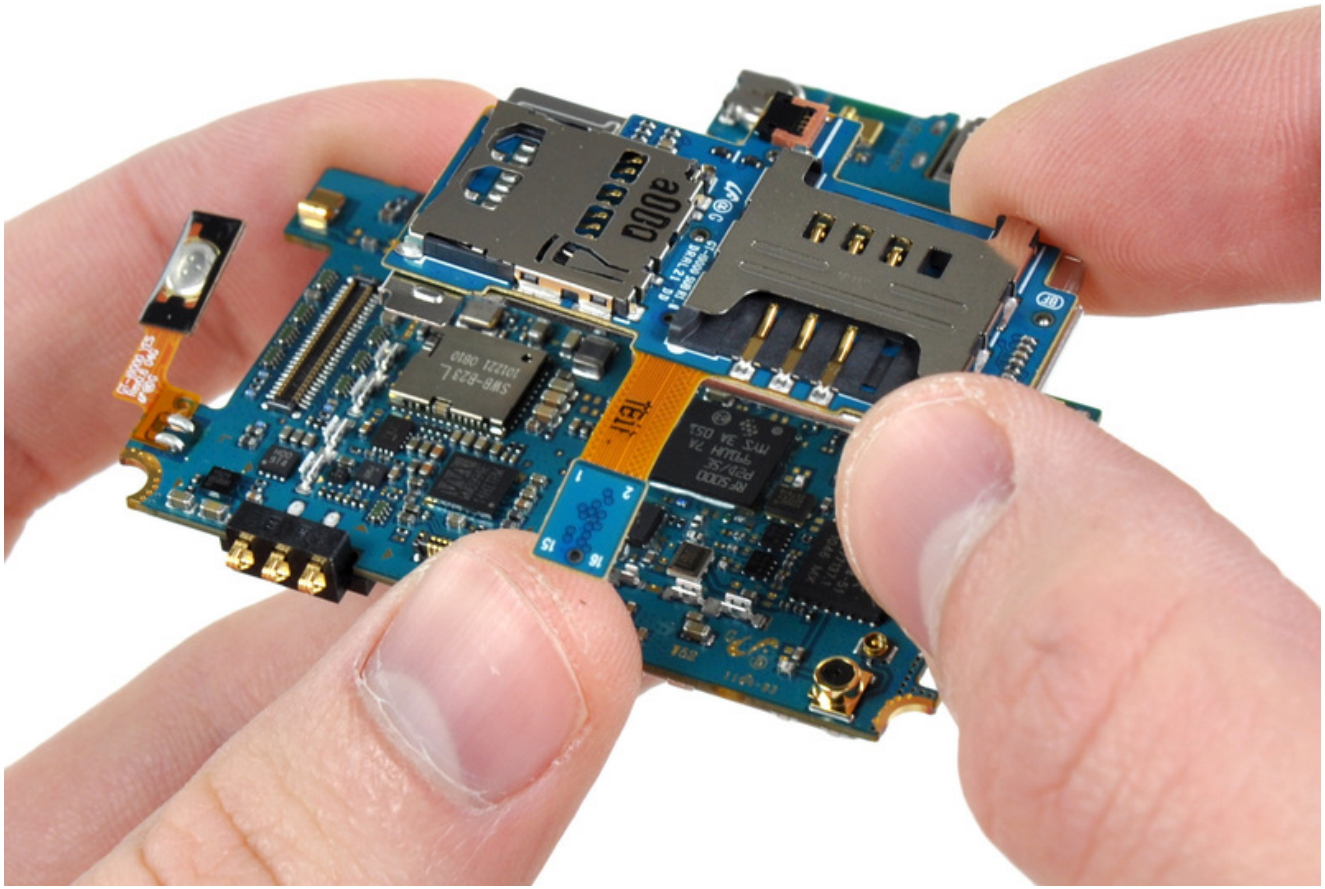
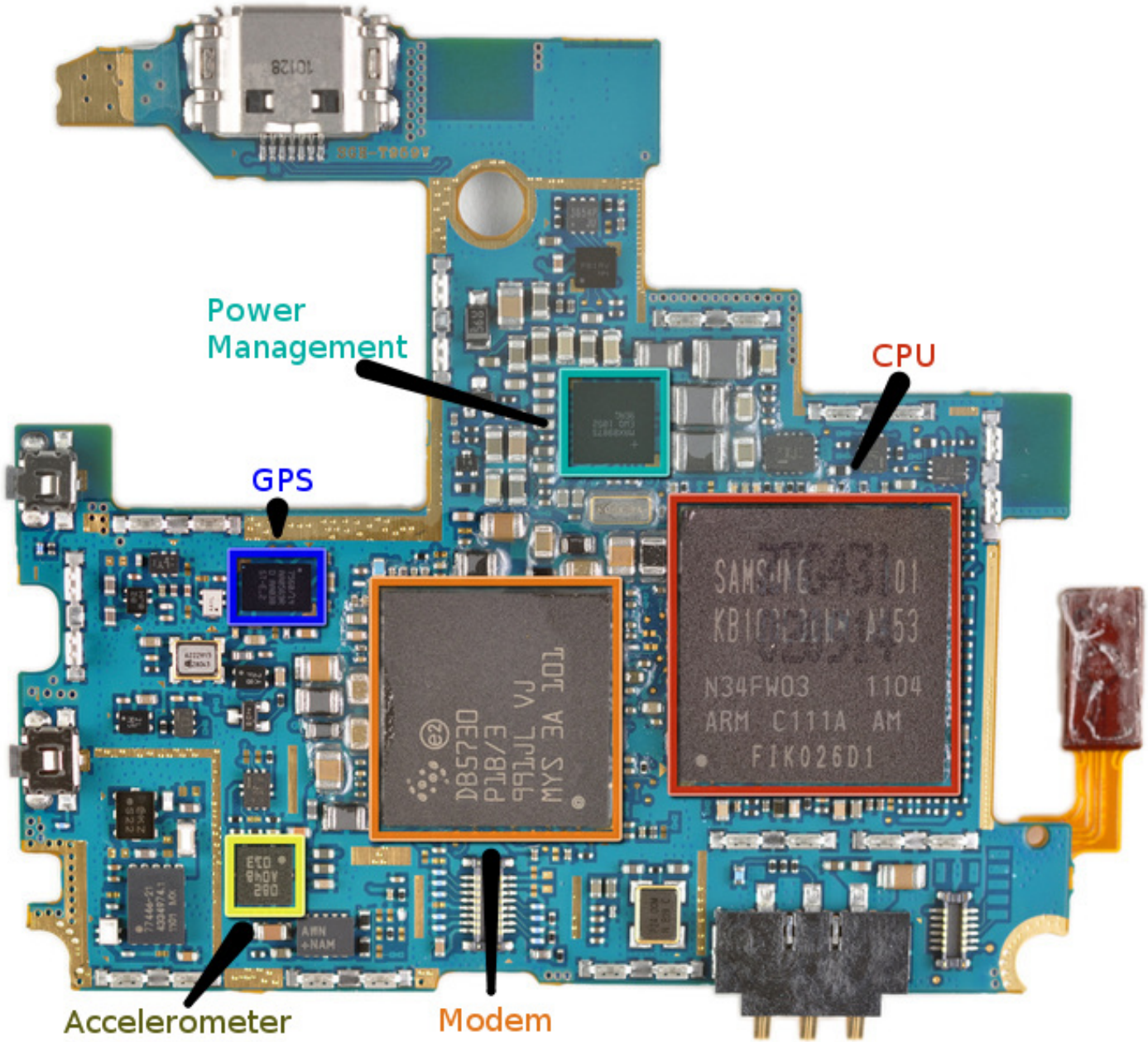




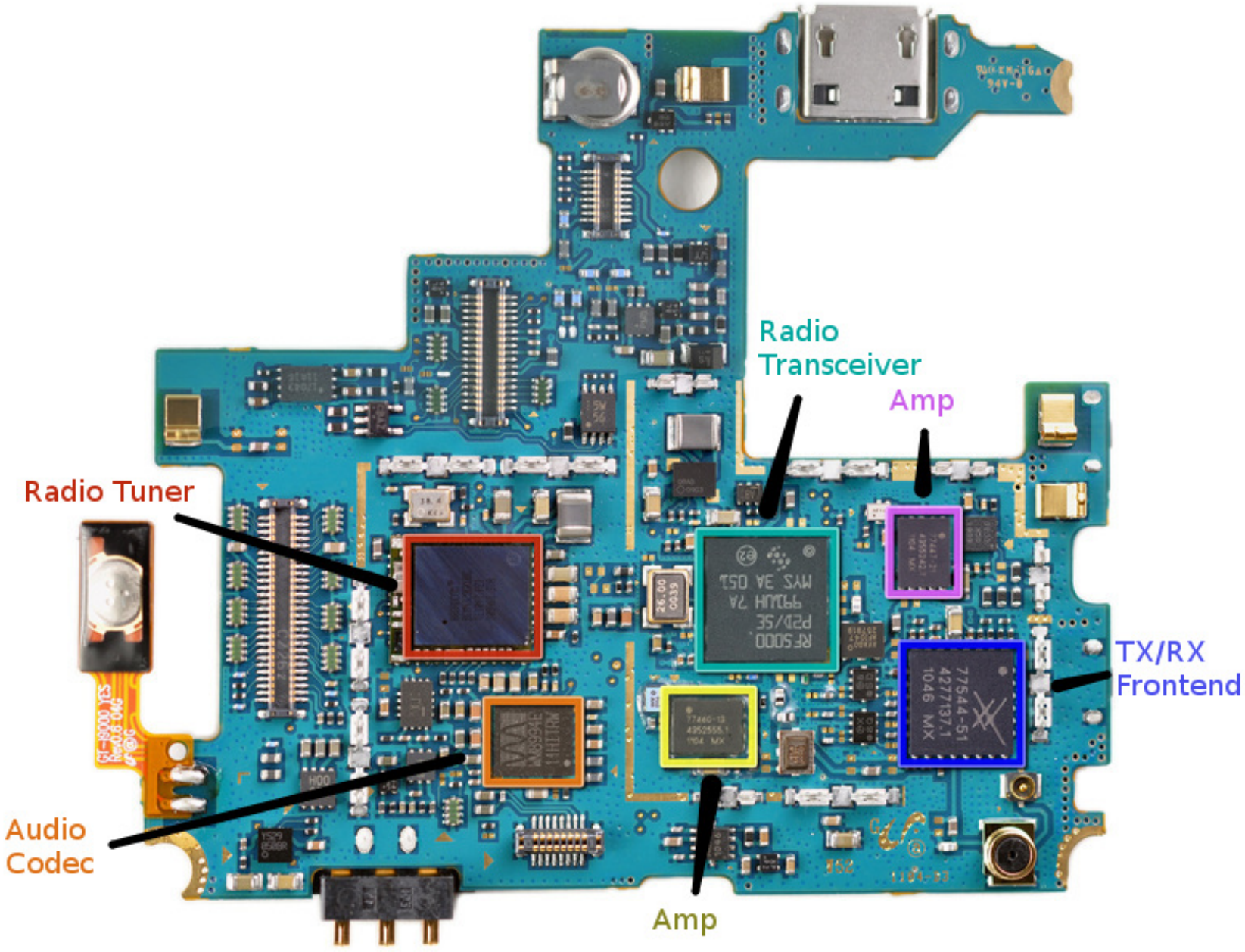
The Motherboard



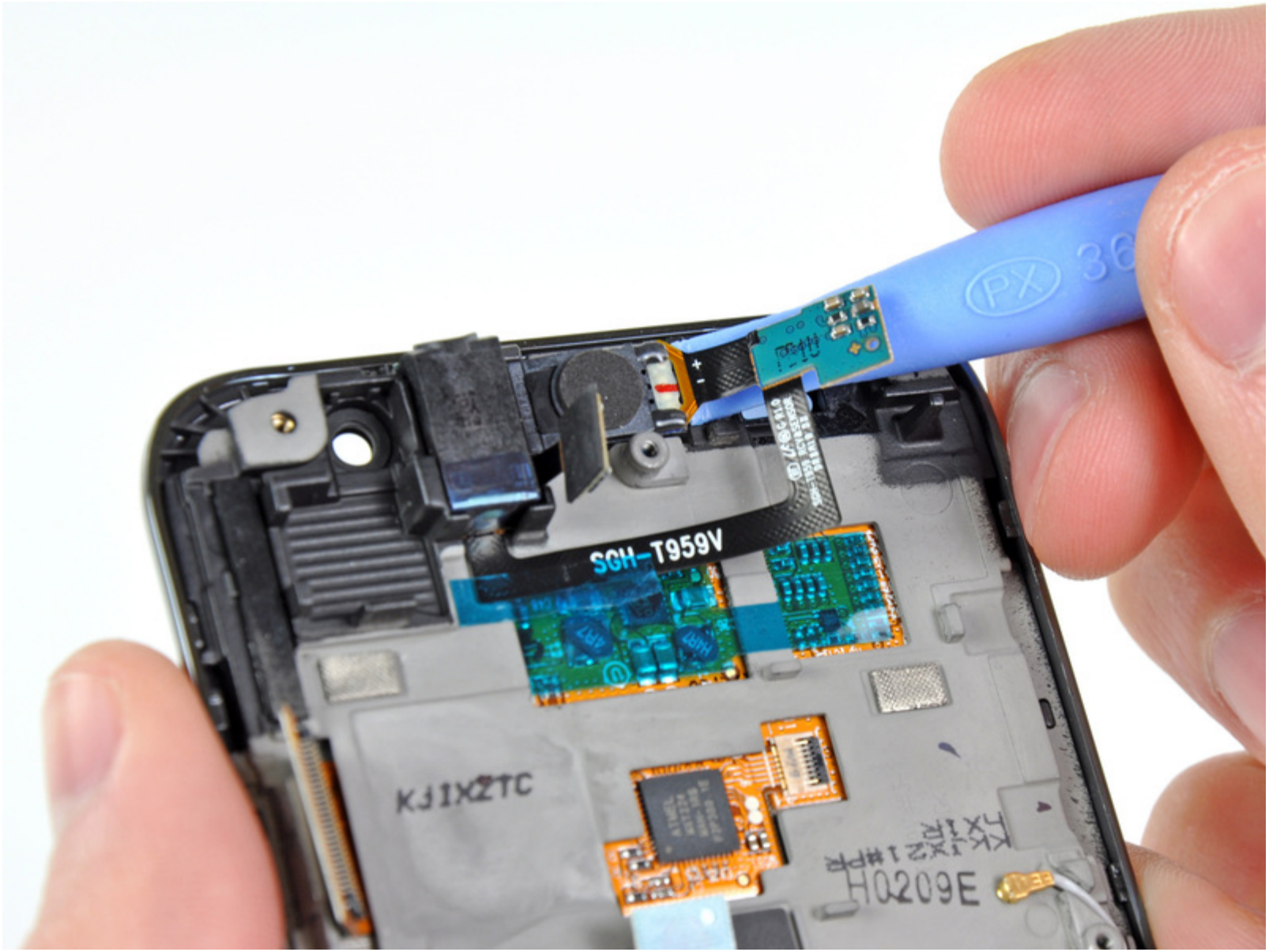
Touring the Motherboard Front



Motherboard Back: Mostly Radios



Headphone Jack, Earpiece Speaker, Proximity/Light Sensor



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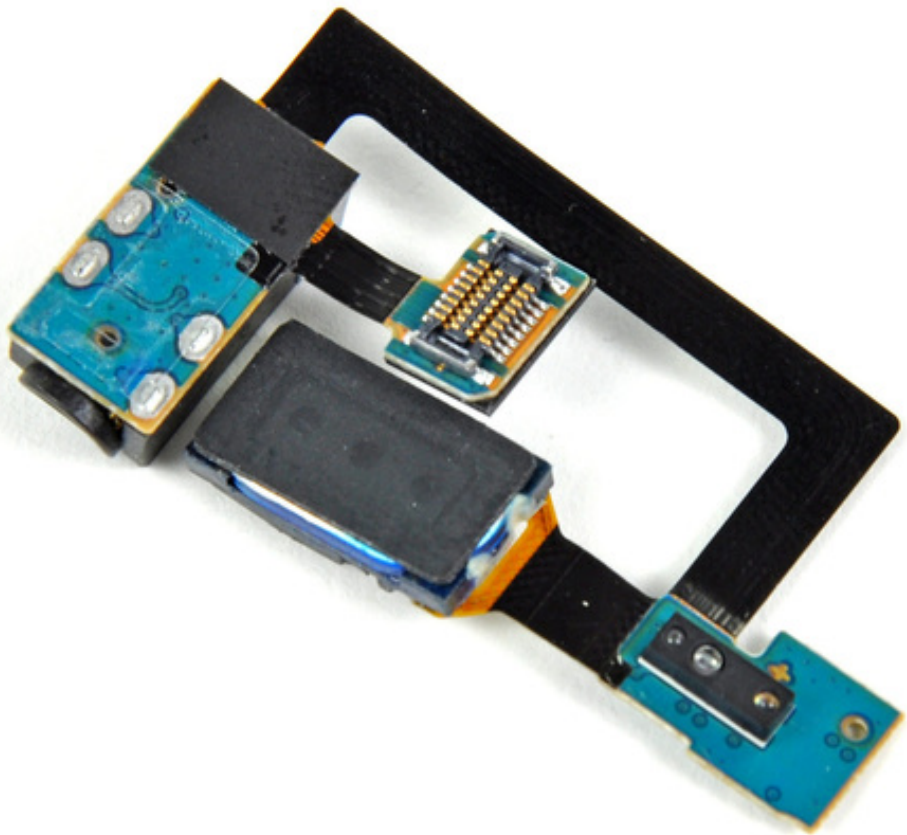
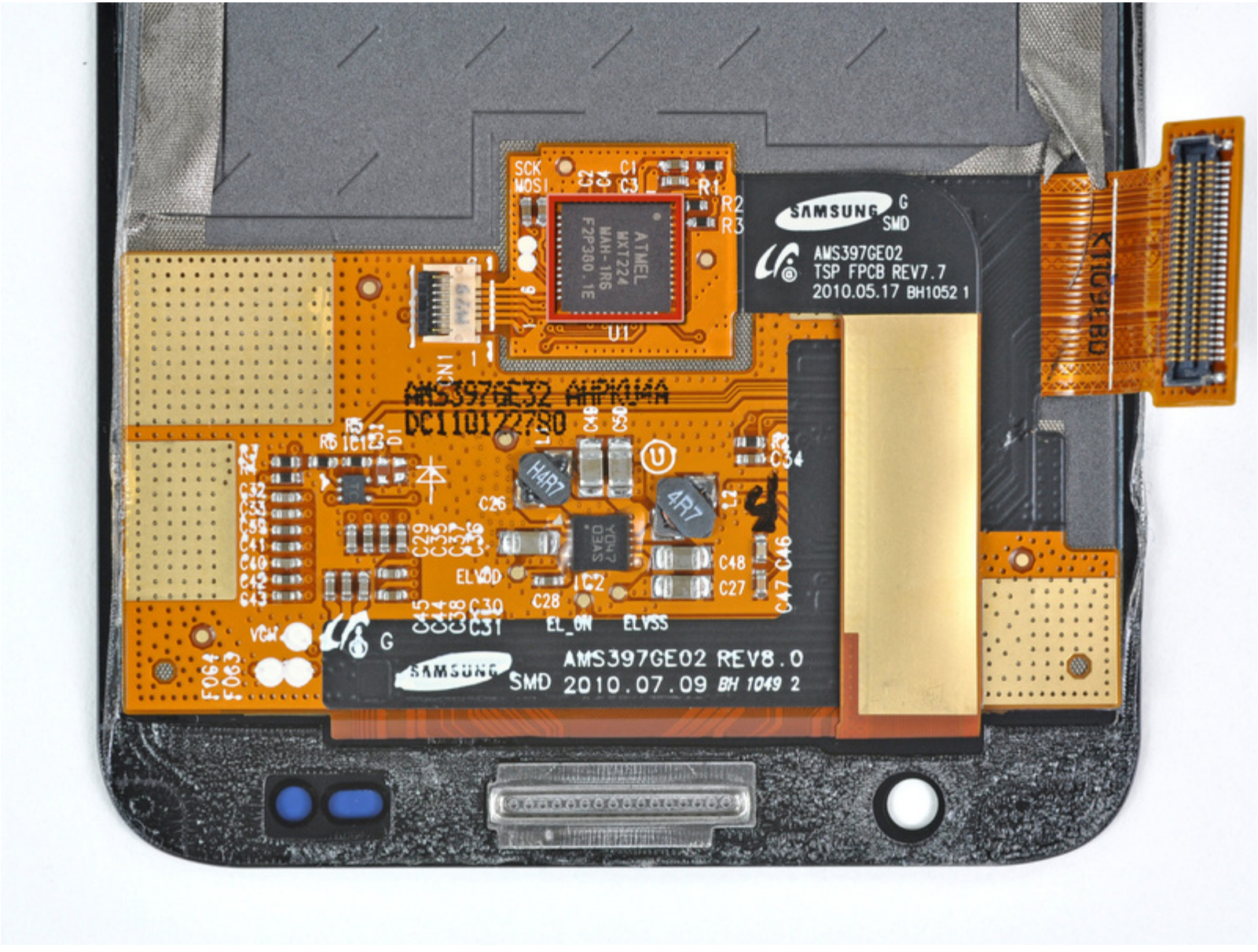
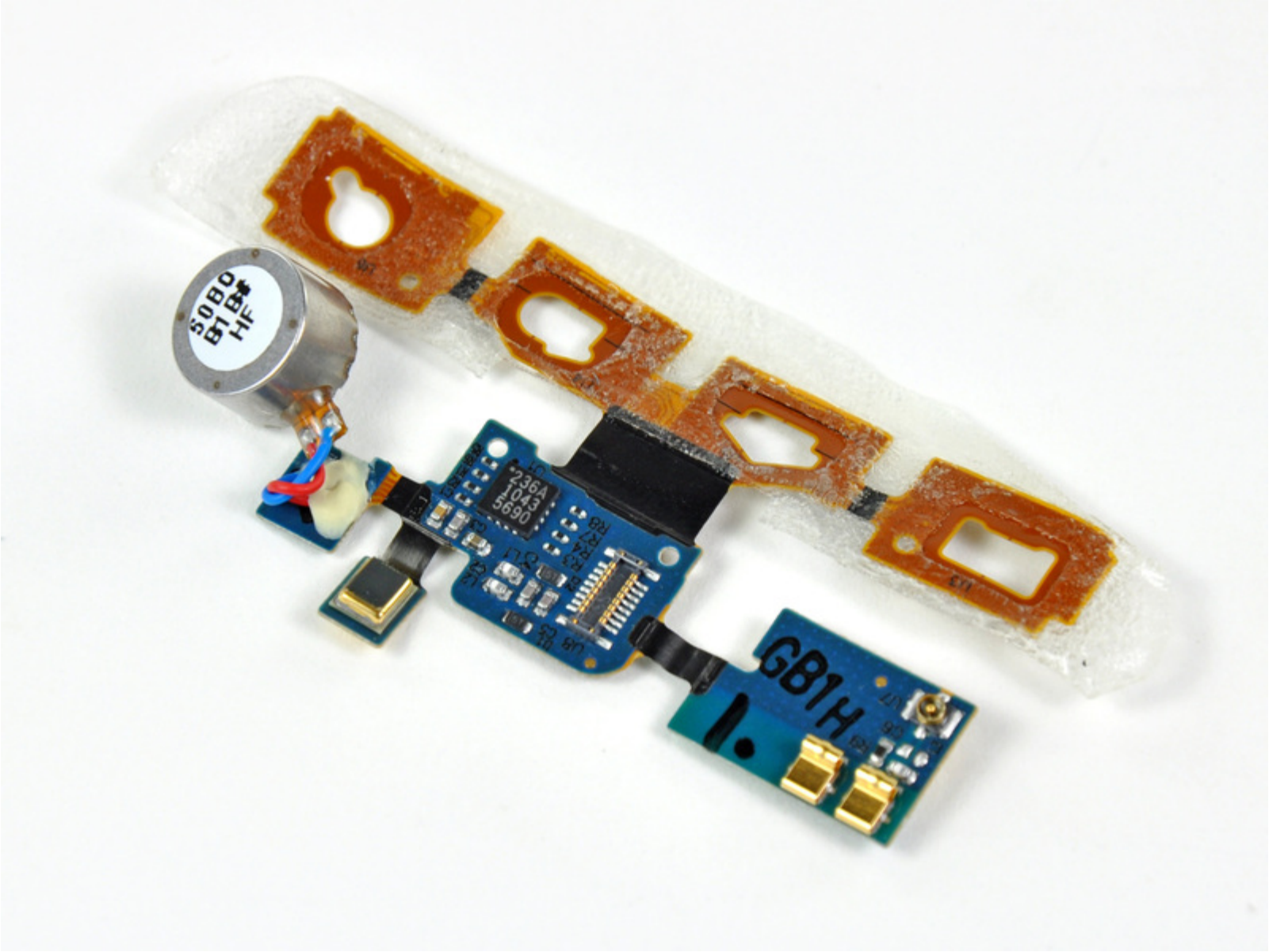


Heat Gun!

Touch Screen Controller



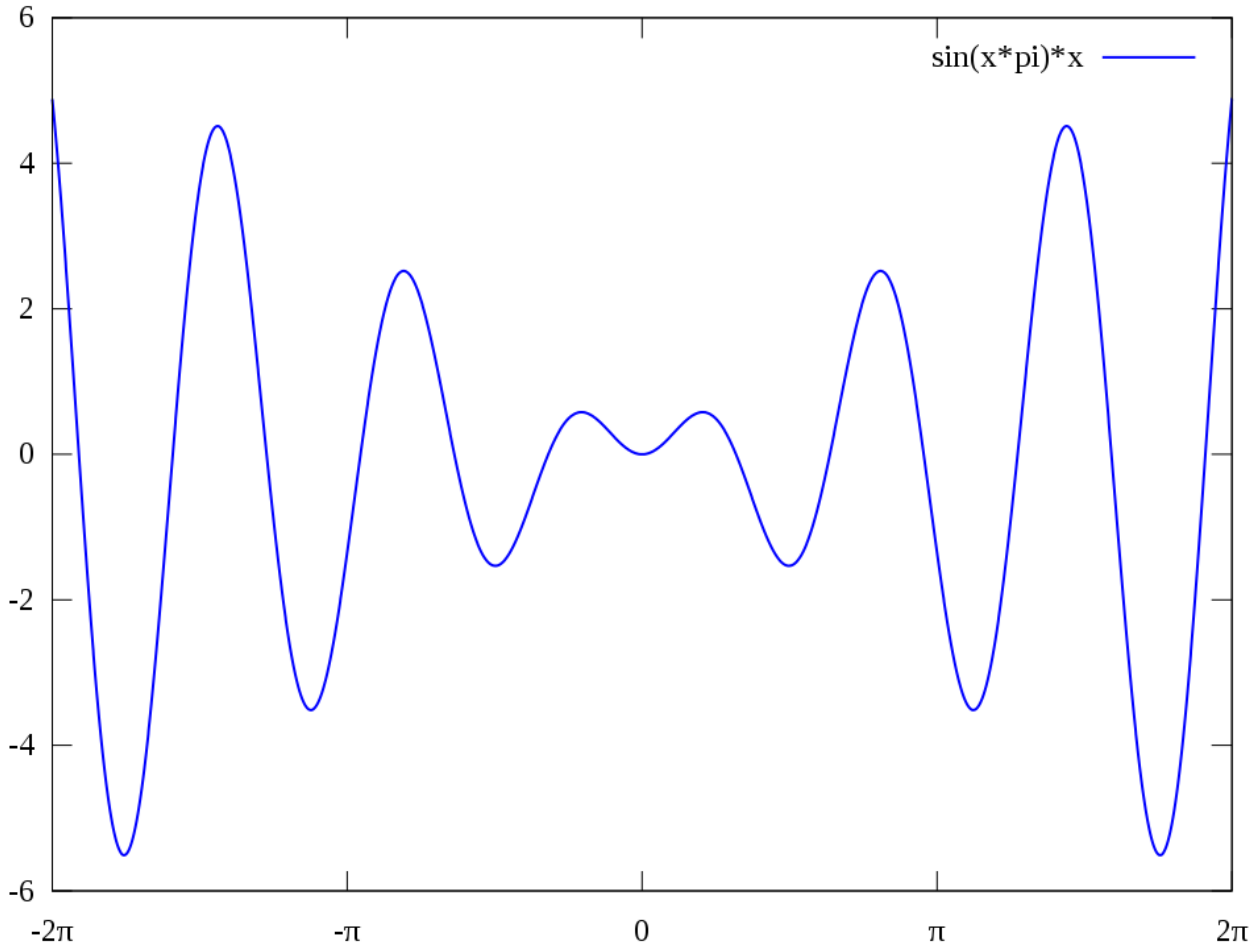
Touch Sensors, Vibrator, Microphone, Antenna Cable



Summing Up

About Sensors

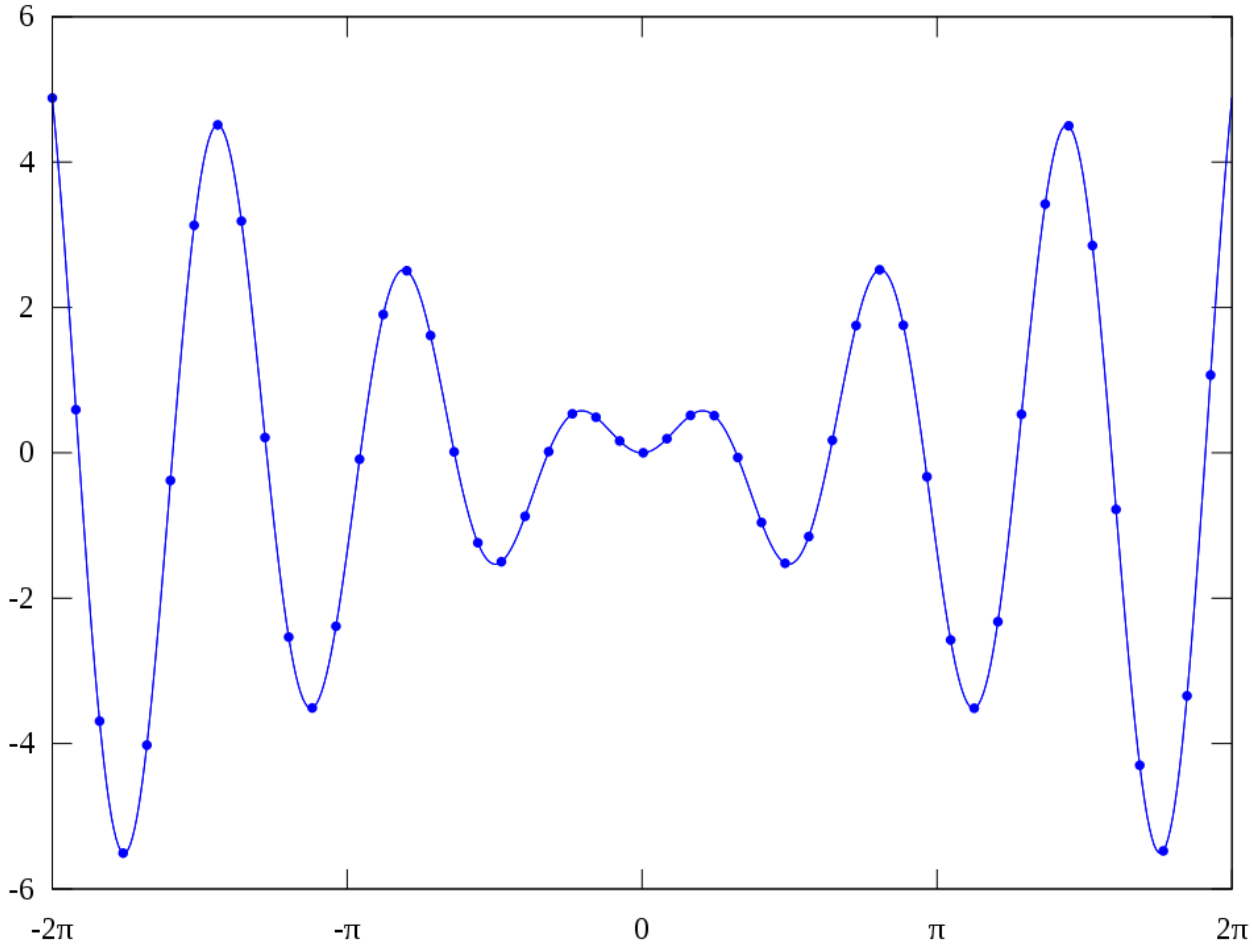
Consider a real-world phenomenon (eg light intensity):



Sensor results (in Volts, say) are continuous and analog.

Computers are discrete-time and digital. What to do?

Answer: Sampling



Report discrete values at given times, e.g.

$$(0, 0), (0.2, 0.12), (0.4, 0.38), (0.6, 0.57), (0.8, 0.47).$$

Analog-to-Digital Converter

(Wolfson Microelectronics WM8994 Audio CODEC)

ADC part of the codec converts continuous-time analog signal to discrete-time digital signal.

ADC Output

We lose information if samples too infrequent[1], or if sample resolution too poor.

Time (ms)	Signal (V)
0.0	0.00
0.2	0.12
0.4	0.38
0.6	0.57
0.8	0.47

How would we increase sample frequency? Sample resolution?

[1] Nyquist sampling theorem.

About Actuators

Actuators convert output from the computer system into some effect on the environment.

What are some examples of actuators?

Some actuators require analog voltage signals;

- feed the discrete-time data to a digital-to-analog converter (**DAC**).

Combined Sensors and Actuators

(Wolfson Microelectronics WM8994 Audio CODEC)

This contains both an ADC and a DAC.
Also, e.g. piezoelectric sensors are both sensors and actuators.

Programming Embedded Systems

— Android 2.3 embedded operating system.

About Android

Example of an embedded operating system.

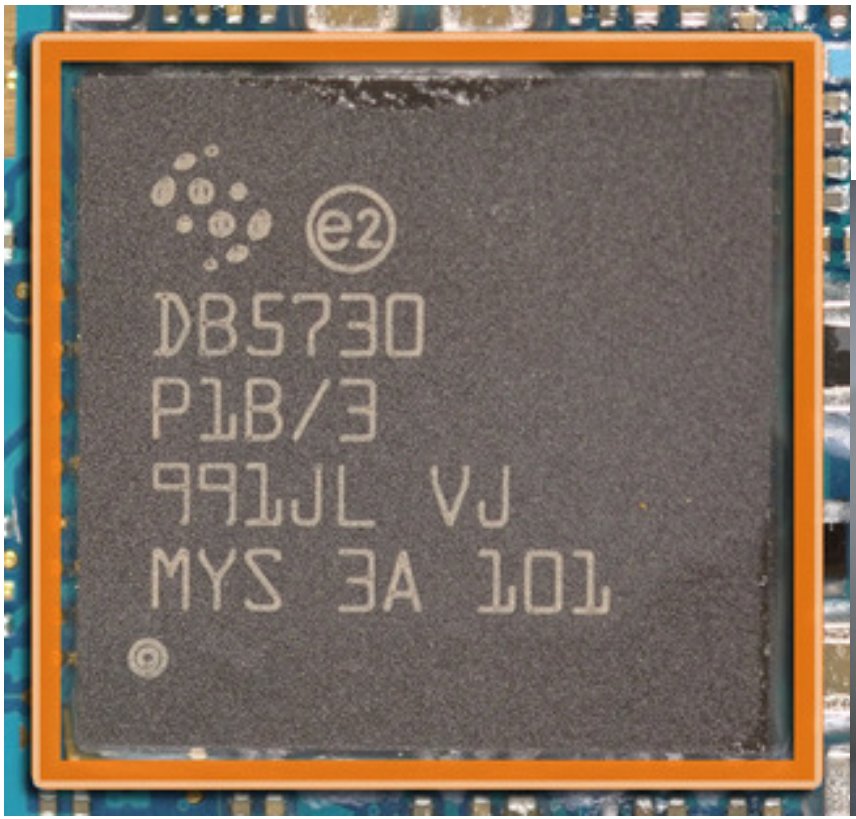
Target: smartphones and tablets.

- Runs Linux under the hood;
- Using Java, insulates applications from the hardware;
- Is compact and efficient;
- Cares about battery life;
- Favours portability;
- Available under an open-source license (Apache).

We'll learn Android programming in this course.

Lower-level Embedded System Programming

Consider the modem:



[2]

Converts encoded (radio) signals to and from bits.

[2] (credit Wilton Ramon de Carvalho Machado, `http://en.wikipedia.org/wiki/File:Fax_modem_antigo.jpg`)

Interacting with a Modem

Running an Embedded Control Program

The modem is running an embedded control program.

- accepts high-level commands from the CPU;
- translates bits into analog signals; contains an ADC and a DAC.

More generally, the modem:

- boots automatically;
- never terminates;
- translates stream of sensor inputs and actuator outputs;
- cares about timing.