Corso di Elettronica dei Sistemi Analogici e Sensori

Course Analog Electronic Systems and Sensors

A.A. 2015/2016

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Orario di ricevimento: Martedi 9-11, Stanza 536

c/o Dipartimento Ingegneria dell'Informazione

Obiettivi del corso

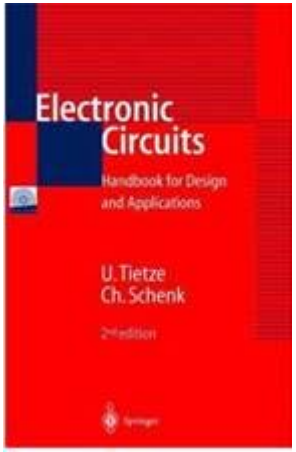
Il corso fornisce gli elementi necessari alla progettazione di sistemi analogici costituiti da sensori/trasduttori e da circuiti elettronici per l'elaborazione analogica dei segnali a banda larga e a banda stretta, con riferimenti alle tecnologie dei circuiti integrati.

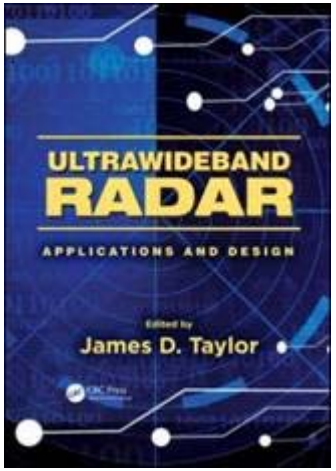
I sistemi di riferimento sono quelli ad ultrasuoni e sensori radar utilizzati in molti settori :medicale, controlli non distruttivi, beni, controlli di processo, sicurezza, automotive,..

Si prevede una serie di esercitazioni di laboratorio con progettazione elettronica e caratterizzazione di front- end elettronico per sensori di temperatura, accelerazione e ultrasuoni.

Testo di riferimento : ***TIETZE SCHENK "Electronic Circuits" Handbook for design and applications , 2nd Edition, Springer***

Testo di consultazione- Ultrawideband Radar, Applications and Design Edited by James D. Taylor - Published 2012 by CRC Press





Diploma Supplement

The course provides the basics for the design of analog electronic systems that include sensors and transducers, narrow band and broadband analog signal processing components and circuits.

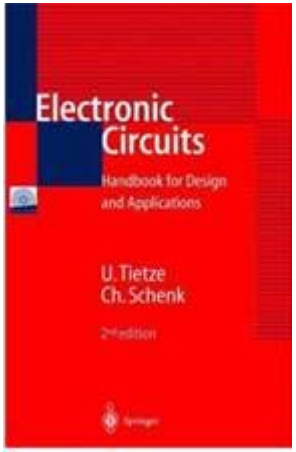
The course refers mainly to ultrasonic and georadar electronic systems devoted to medical and non destructive testing applications.

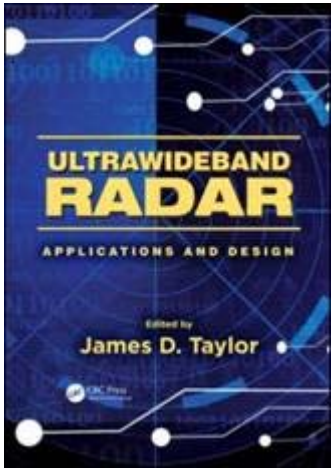
A series of laboratory units are part of the course for the design and characterization of analog front end for different kind of transducers and signal processing blocks for the transmission and interface to A/D circuits.

Text books

- TIETZE SCHENK "Electronic Circuits" Handbook for design and applications , 2nd Edition, Springer

- Ultrawideband Radar, Applications and Design Edited by James D. Taylor - Published 2012 by CRC Press





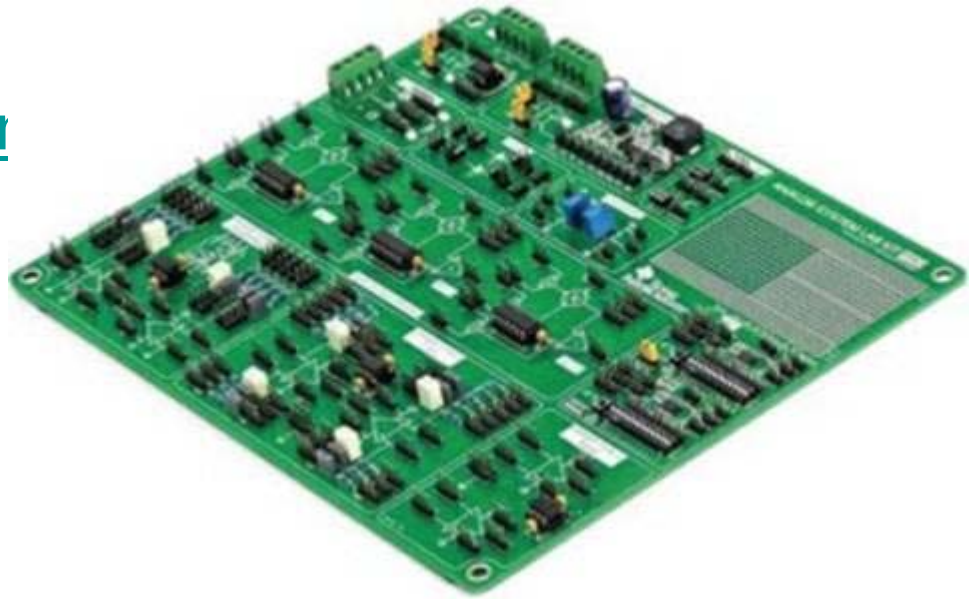
Materiale didattico

Il materiale didattico verra' distribuito in forma di presentazioni, articoli scientifici di *review*, documenti tecnici il materiale didattico relativo alle lezioni, seminari ed esercitazioni.

(visita il sito del Laboratorio Ultrasuoni e Controlli Non Distruttivi http://www.uscndlab.dinfo.unifi.it)

Per le esercitazioni si farà uso di ANALOG SYSTEM KIT di Texas Instruments:

http://www.ti.com/ww/eu/ur
ems_Lab_Manual_en.pdf

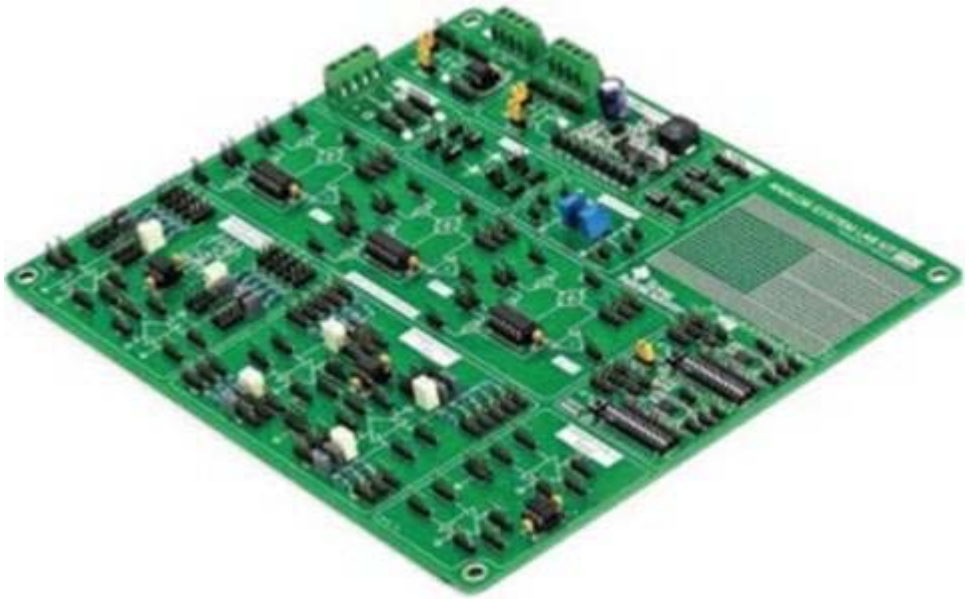


Course supporting material

The material will be delivered to participants in the form of slides, *review* articles, technical documents of components and lecture notes, seminar presentations and exercise examples.

For the laboratory units will be used the ANALOG SYSTEM KIT of Texas Instruments:

http://www.ti.com/ww/eu/university/brochures/Analog_Systems_Lab_Manual_en.pdf



Modalità di verifica dell'apprendimento

E’ prevista la frequenza alle esercitazioni di laboratorio.
Le relazioni scritte delle esperienze di laboratorio, da consegnare entro 7 gg dopo la fine dell’esercitazione per una discussione plenaria con tutti i gruppi.

Prova orale finale sulle relazioni delle esercitazioni con approfondimenti su argomenti di teoria.

Programma dettagliato del corso

Corso Elettronica dei Sistemi Analogici e Sensori AA 2015-2016

Criteri generali della progettazione dei sistemi analogici con sensori.

Generalità sui sensori. Temperatura (Termistori, termocoppie) , linearizzazione della risposta di sensori (es. sensori di temperatura PTC/NTC), accelerometri MEMS capacitivi, estensimetri (resistivi), sensori piezoelettrici (pressione, microfoni).

Circuiti per interfacciamento dei sensori con strumentazione di misura:

- Isolamento galvanico ottico o a trasformatore,
- Amplificatori di isolamento di tipo ottico e a trasformatore
- Amplificatore per Strumentazione
- Amplificatori di trans impedenza (CCVS) e trans conduttanza (VCCS) e loro applicazione nei sistemi di trasmissione diretta dei segnali
- Convertitori V/F e F/V

Bus di controllo per sistemi analogici

SPI, I2C, RS232, current loop 4-20 mA
Esempi di interfacciamento con microcontrollore

Circuiti e dispositivi per sistemi di elaborazione analogica dei segnali:

- Amplificatori operazionali speciali:
- Amplificatori a Chopper (applicazioni con termistori, rivelatori di fase)
- Amplificatori a Singola alimentazione (single-supply)
- Amplificatori Rail - to - Rail
- Amplificatori a basso rumore (LNA)
- Amplificatori a Guadagno variabile statico e dinamico (VGA , TGC, AGC)
- Amplificatori a larga banda e tecniche di compensazione
- Moltiplicatori analogici

Amplificatori di potenza lineari

Configurazioni per amplificatore in classe A,B, AB, D. Analisi e confronto delle caratteristiche: rendimento, impedenza di uscita, banda, distorsione armonica totale e di intermodulazione

Elettronica per sistemi ad ultrasuoni

- Trasduttori ad ultrasuoni: principio di funzionamento e tecnologie costruttive
- Generatori di impulsi ad elevata tensione.
- Circuiti disaccoppiatori, tosatori: singola soglia, doppia soglia, tosatore simmetrico, esempio applicativo ai trasduttori ad ultrasuoni
- Demodulatore sincrono analogico e digitale
- Circuiti per l'estrazione dei segnali in fase e quadratura: esempio di catena per effetto Doppler ad ultrasuoni e per sensore radar di tipo olografico.

ESERCITAZIONI

1. Sistema di misura di temperatura differenziale con termocoppie
2. Caratterizzazione di un circuito per la misura di modi vibrazionali con accelerometri MEMS
3. Progetto di un sistema di misura della distanza ad ultrasuoni in aria
4. Progetto finale

SEMINARI

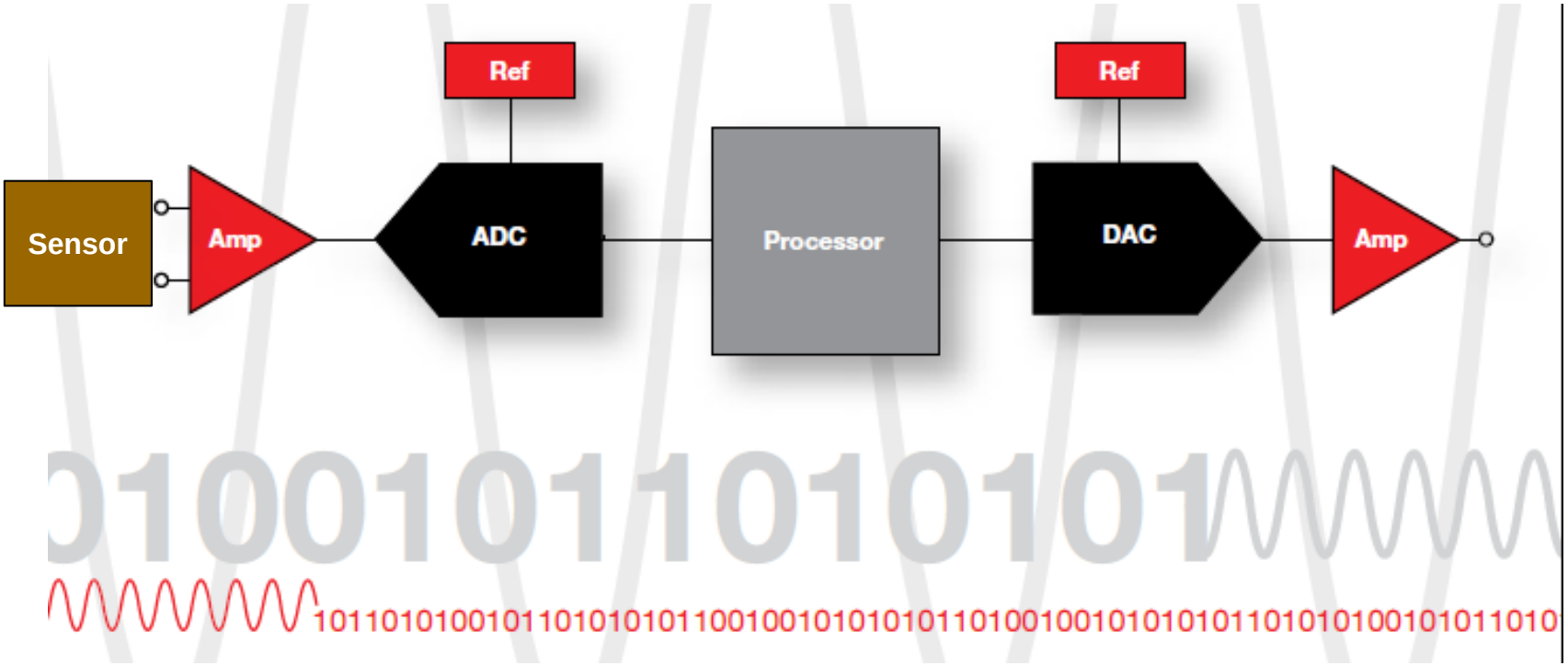
- Sono previsti seminari da parte di Texas Instruments e da parte di docenti e ricercatori di altri istituti di ricerca italiani o stranieri.
- Seminari su Elettronica per sistemi con sensori radar:
- Analisi schemi a blocchi e della componentistica (VCO, rivelatore di inviluppo, mixer) dei radar penetranti a impulsi (UWB) e a banda stretta(FM/CW)
- Seminario su applicazioni robotiche dei sistemi di scansione con radar olografico : principio di funzionamento dell'olografia a microonde, architettura del sistema robotico
-

Esercitazioni di Elettronica dei sistemi analogici e sensori - I° Periodo 21/09/2015 al 18/12/2015 A.A. 2015-2016

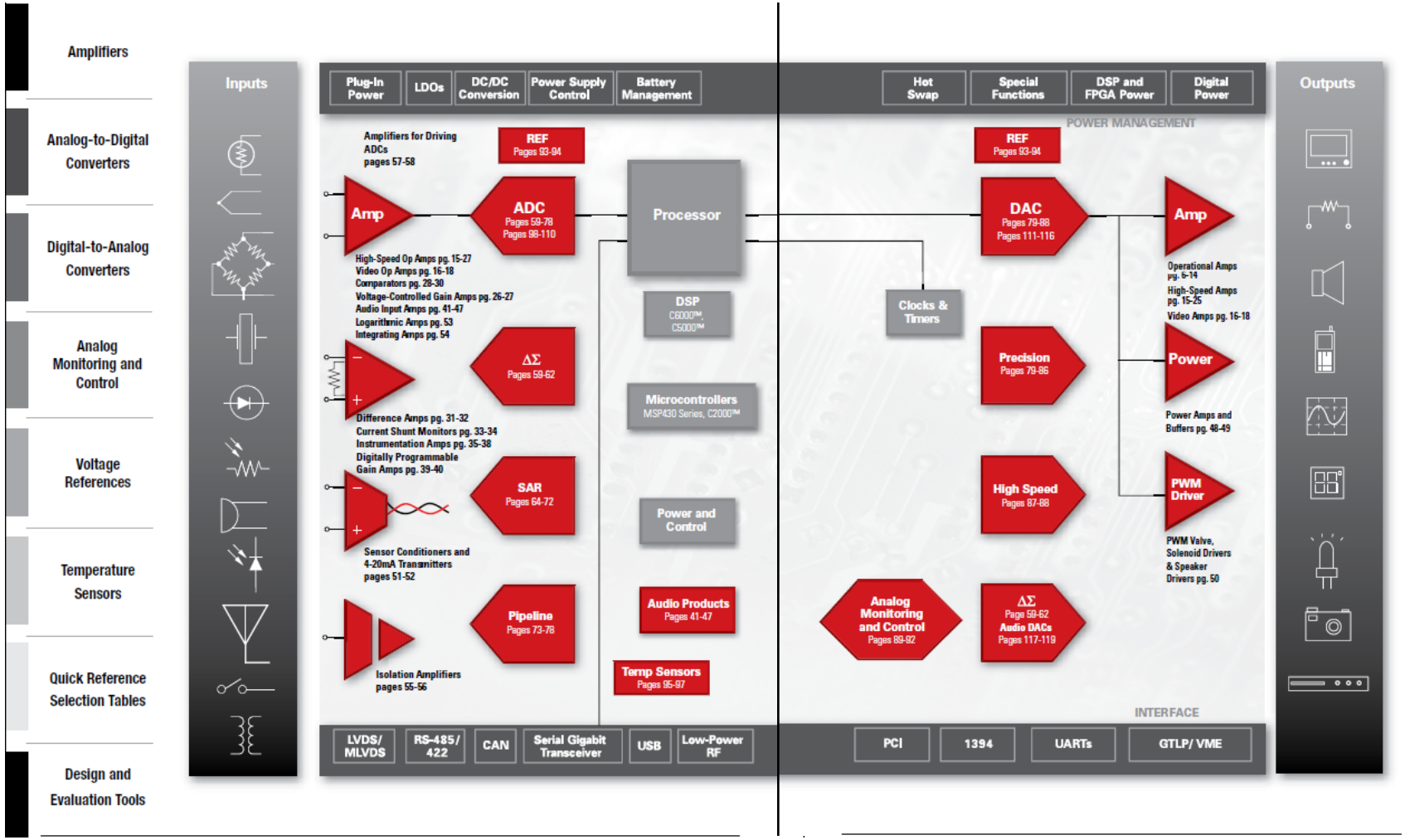
Eserc. #	Data	Oggetto esercitazione	Assistenti	Tipologia
1	25/9/15	**Presentazione scheda Analog System Lab KIT Texas Instruments**	Giombetti/Calzolai/Giannelli	
2	8/10/15	**Accelerometri MEMS**	Bulletti/ Giombetti	Misure
3	28/10/14	**Circuito con termocoppie differenziali**	Giombetti/Chini	Caratterizzazione e misure
4	6/11/15	**Progetto di un sonar con trasduttori ad ultrasuoni in aria:**	Chini/Calzolai/Giannelli/Bulletti	Realizzazione e e Misure
5	19/11/15	**Sviluppo progetto su scheda TI ASKL**	Bulletti/Calzolai/Giombetti/Giannelli/Capineri	Progetto e simulazione
6	27/11/15	**Sviluppo progetto su scheda TI ASKL**	Bulletti/Calzolai/Giombetti/Giannelli/Capineri	Realizzazione
7	4/12/15	**Sviluppo progetto su scheda TI ASKL**	Bulletti/Calzolai/Giombetti/Giannelli/Capineri	Realizzazione e misure
8	11/12/14	**Verifica sperimentale progetto e impostazione relazione finale**	Bulletti/Calzolai/Giombetti/Giannelli/Capineri	Documentazione/ relazione

Info: Esercitazioni presso il Laboratorio Didattico Area dell'Informazione, Tel 055 2758506
Tecnico di Laboratorio : Sig Andrea Giombetti Piergentili giombetti @ unifi.it Tel 0552758608
Assistenti di Laboratorio: Prof. Antonio Chini, Sig Marco Calzolai, Ing Andrea Bulletti, Ing Pietro Giannelli

Analog Electronic Systems: signal chain



Analog Electronic Systems: sensors and devices



Why sensors are important?

Sensors, Artificial Intelligence, Robotics….

Moravec's paradox is the discovery by artificial intelligence and robotics researchers that, contrary to traditional assumptions, high-level reasoning requires very little computation, but low-level sensorimotor skills require enormous computational resources. The principle was articulated by Hans Moravec, Rodney Brooks, Marvin Minsky and others in the 1980s.

As Moravec writes, "it is comparatively easy to make computers exhibit adult level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility."[1]

[1] Moravec, Hans (1988), *Mind Children*, Harvard University Press

…and the Moore Law

…I've been known for making grand pronouncements at lithography conferences about the coming end of Moore's Law. But the truth is, I don't think Moore's Law is over. Instead, I'd argue it's on the verge of morphing again…..
…. Chip designers have just begun exploring how to integrate MEMS (*), which can be used to make tiny accelerometers, gyroscopes, and even relay logic(**). The same goes for microfluidic sensors, which can be used to perform biological assays and environmental tests.
All of these technologies allow you to directly connect a digital CMOS chip with the outside, analog world. This could have a powerful economic effect if the new sensors and actuators can take advantage of the low-cost, mass-production approaches common to silicon manufacturing. [2]

(*) microelectromechanical systems (MEMS)
(**) MEMS Switches for Low-Power Logic

[2] The Multiple Lives of Moore's Law, Why Gordon Moore's grand prediction has endured for 50 years By Chris Mack Posted 30 Mar 2015, Spectrum , IEEE

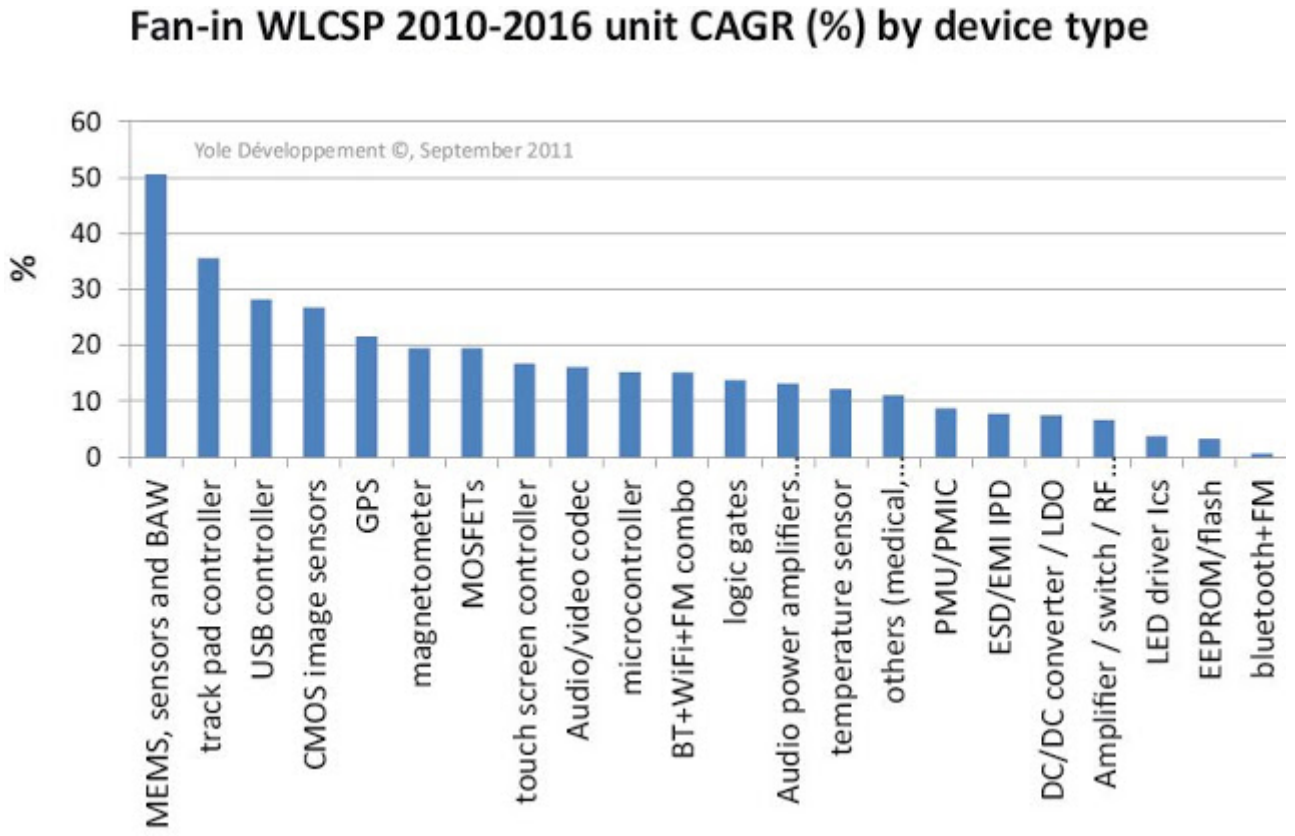
Sensor, environment and human evolution

As Moravec writes:

…Encoded in the large, highly evolved sensory and motor portions of the human brain is a billion years of experience about the nature of the world and how to survive in it. The deliberate process we call reasoning is, I believe, the thinnest veneer of human thought, effective only because it is supported by this much older and much more powerful, though usually unconscious, sensorimotor knowledge. We are all prodigious olympians in perceptual and motor areas, so good that we make the difficult look easy. Abstract thought, though, is a new trick, perhaps less than 100 thousand years old. We have not yet mastered it. It is not all that intrinsically difficult; it just seems so when we do it.[3]…

[3] Moravec, Hans (1988), *Mind Children*, Harvard University Press

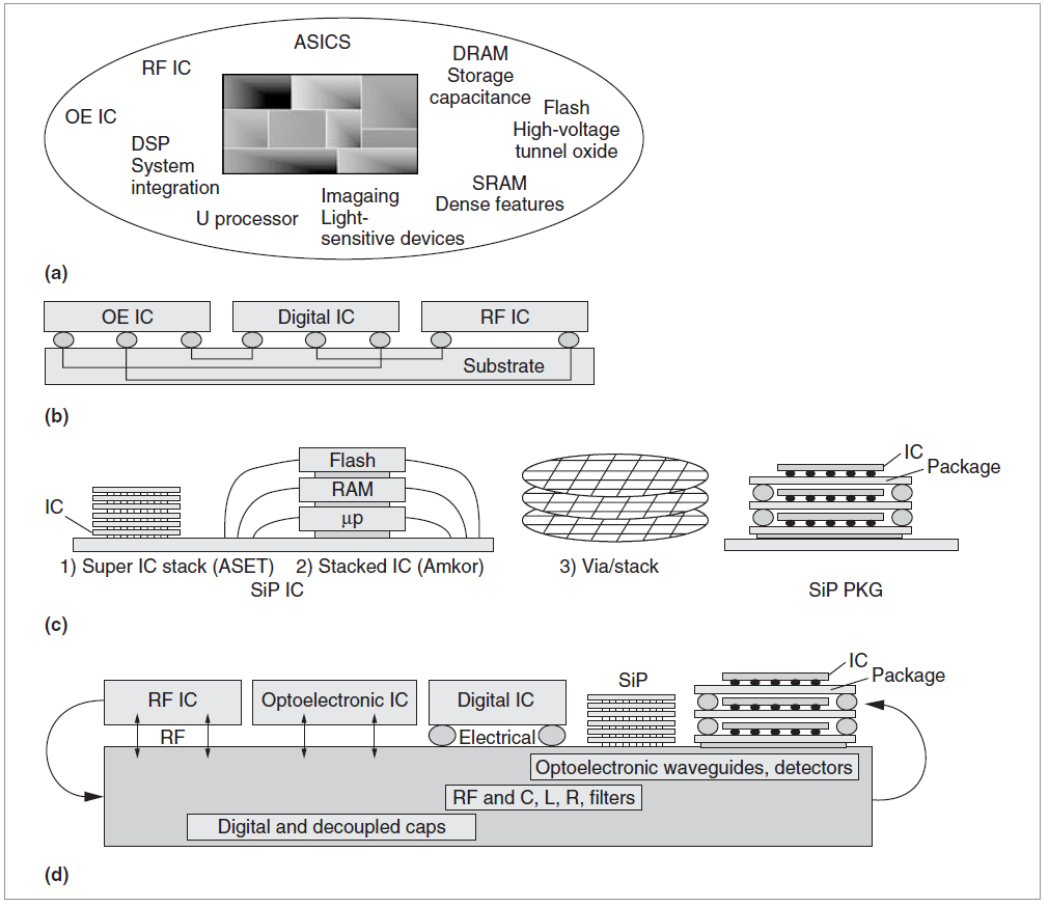
Electronic Sensors Markets



Wafer Level Chip Scale Packaging (WLCSP) refers to the technology of packaging an integrated circuit at wafer level, resulting in a device practically the same size as the die

C.A.G.R. (Compound Annual Growth Rate)

Analog systems integration



a) **a complete system on one chip (SoC) ;**
b) **multichip module (MCM) using interconnected components ;**
c) **system in package (SiP) using stacked chip or package for reduced form factors ;**
d) **system on package (SoP), which offers the best of IC and packaging technologies by optimizing functions between ICs and the package while miniaturizing the systems .**

Analog systems integration

Wafer Level Chip Scale Packaging (WLCSP) refers to the technology of packaging an integrated circuit at wafer level, resulting in a device practically the same size as the die.

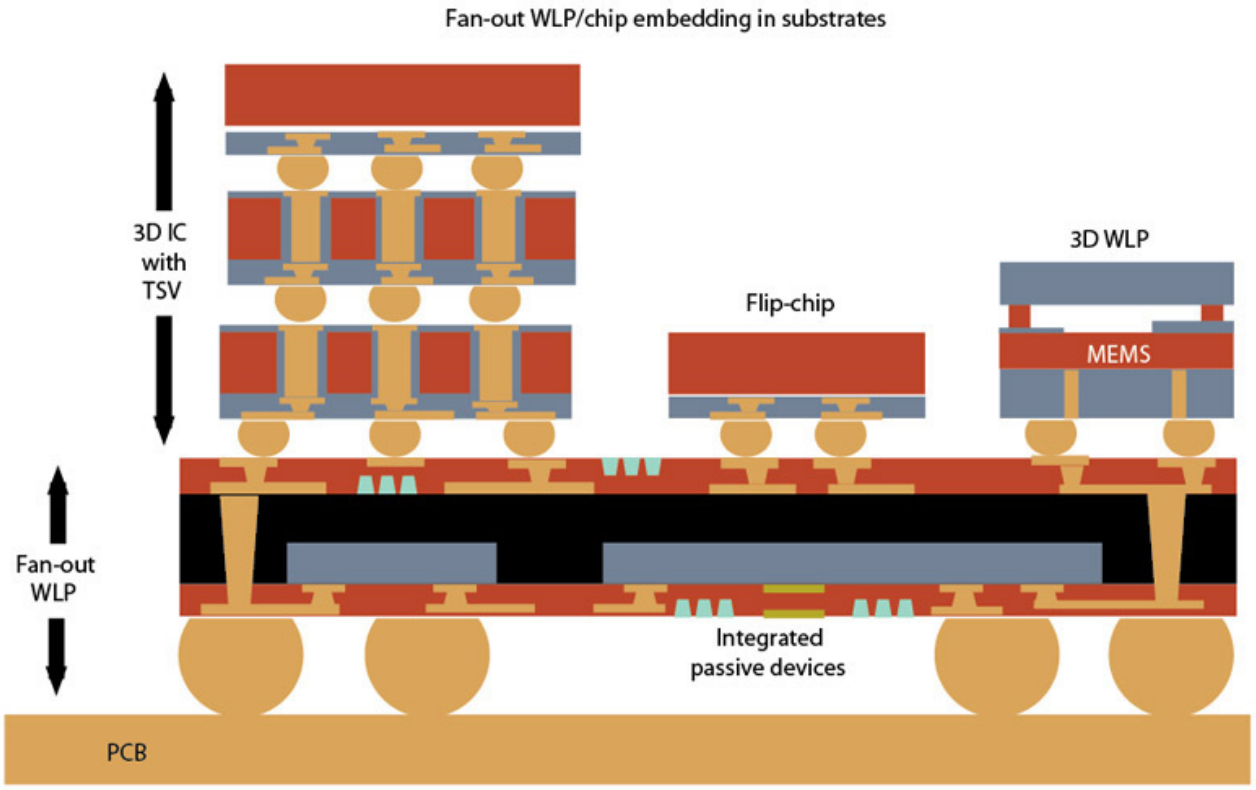


Figure 2. Future 3D IC packaging approaches will embody techniques such as wafer-level packaging (WLP) using through-silicon vias (TSVs) together with embedding chips into various substrates. (courtesy of Yolé Développment)

Electronic Sensors Markets

The Global Temperature Sensors Market

Trends, Drivers & Projections

April 2015

KEY MARKET DRIVERS

- Legislation of Stringent Environmental and Safety Standards
- Adoption of Automated Process Monitoring & Control Solutions in the Industrial Sector
- Growing Use of Multi-Functional Temperature Sensors in Smartphones
- Expanding Applications in Food, Pulp & Paper, and Oil & Gas Industries
- Demand for Smart & Miniature Temperature Sensors in the Consumer Electronics Industry
- Strong Demand for Non-Contact Temperature Sensors

GROWTH PROJECTIONS IN KEY PRODUCT SEGMENTS

- Thermocouple
- Resistance Thermometers
- Integrated Circuit Temperature Sensors (Fastest Growing at 6.8% CAGR)
- Thermistors
- Others

TOP THREE REGIONAL MARKETS THAT HAVE THE MOST POTENTIAL FOR GROWTH

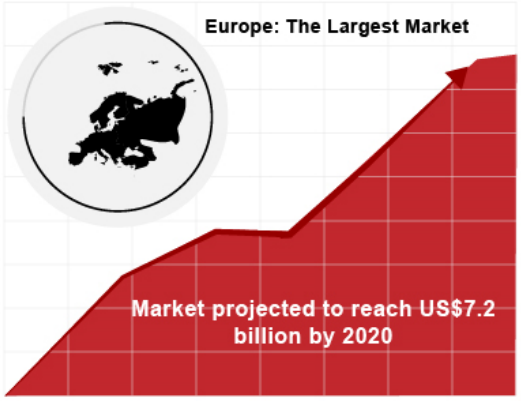
Canada

Latin America

Asia-Pacific

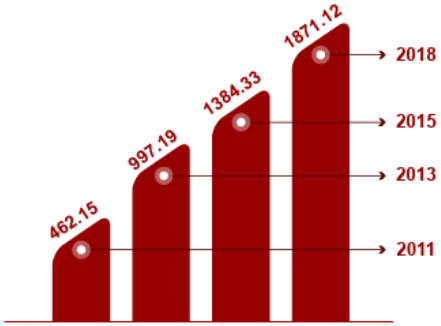
(Compounded Annual Growth in Temperature Sensor Revenues will top 7.8% through 2020)

GLOBAL MARKET SHARE, SIZE & DEMAND FORECASTS

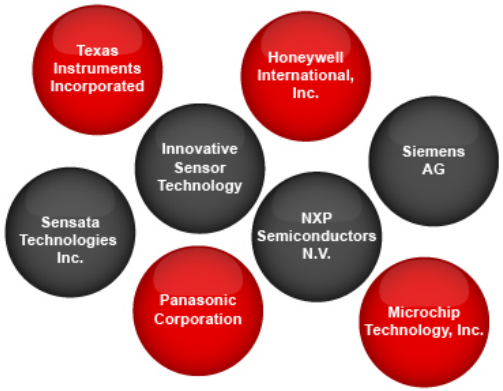


GROWING USE OF TEMPERATURE SENSORS INSMARTPHONES: A KEY TREND

Rising Global Sales of Sensor Packed Smartphones (In Million Units): A Measure of Addressable Opportunity for Integration of Temperature Sensors in Smartphones



COMPETITION



Electronic Sensors Markets

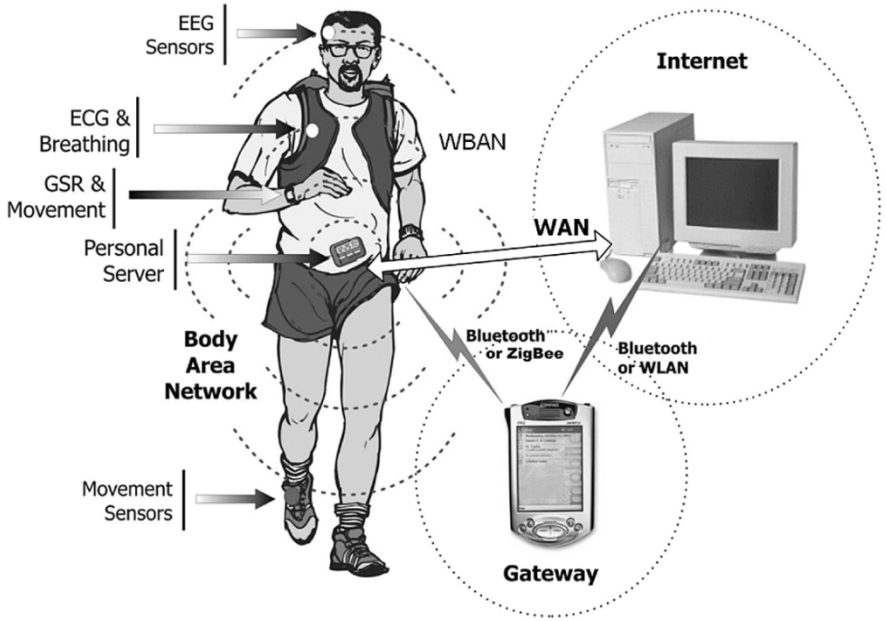
Sensors Chart

Units (Millions)

	2012	2013	2014	2015	2016	2017	CAGR (2012 -2017)	CAGR (2013 -2017)
Accelerometers	1,120.0	1,627.7	1,800.0	1,982.6	2,137.3	2,249.7	15%	8.4%
Gyroscopes	460.5	692.5	900.1	1080.1	1315.3	1544.0	27%	22.2%
Magnetometers	793.7	1,026.6	1,281.9	1,481.9	1,623.9	1,734.1	17%	14.0%
Pressure	83.0	179.3	305.7	514.7	668.0	792.8	57%	45.0%
Grand Total	**2457.2**	**3526.1**	**4287.7**	**5059.2**	**5744.5**	**6320.6**	**20.8%**	**15.7%**

Source: IHS

Emerging market: wearable devices



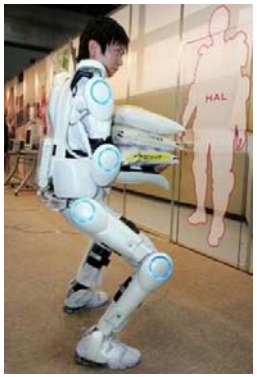
E-Health

E-Textiles

Interactive games

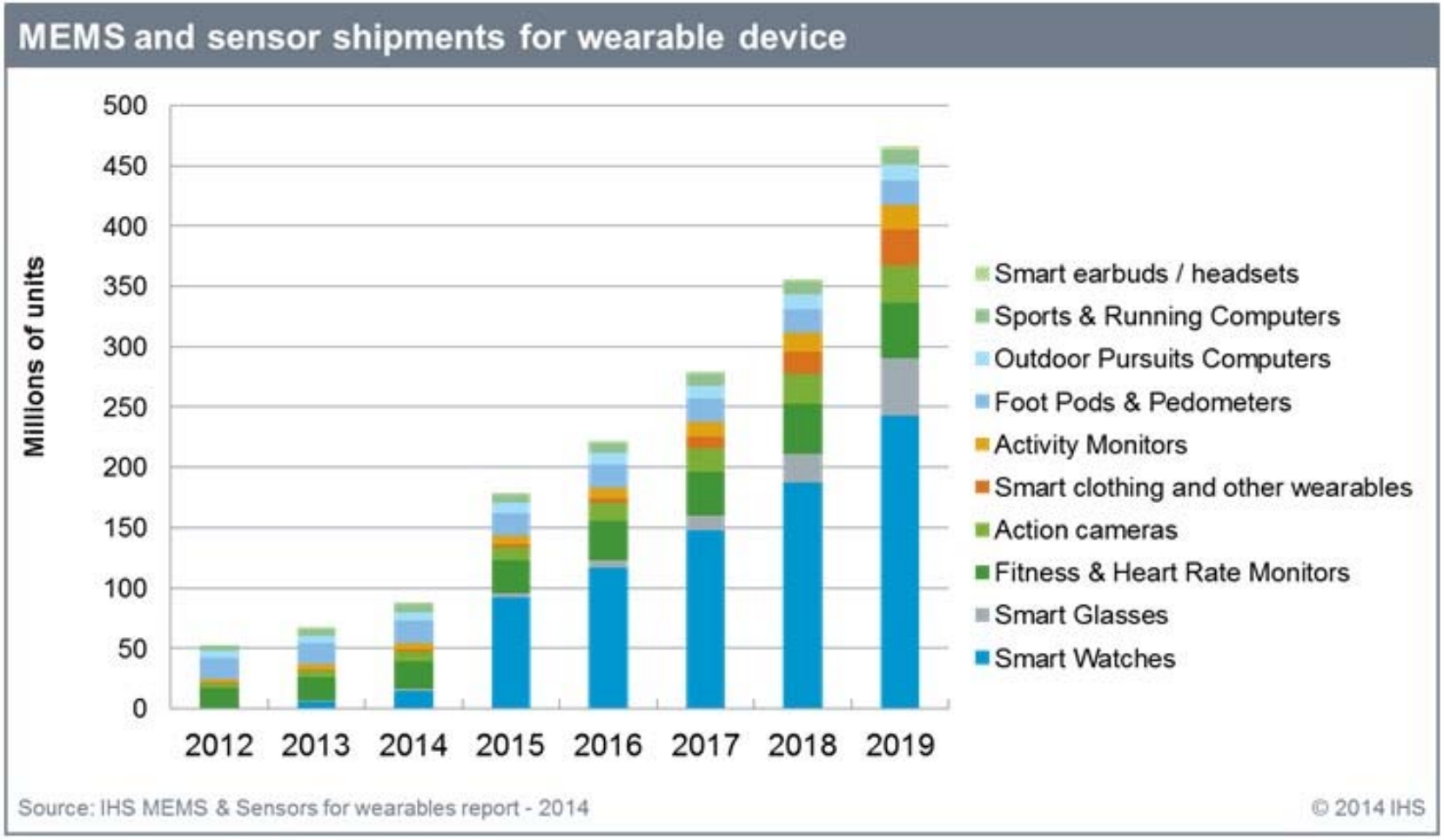
Military

Bio Medicine

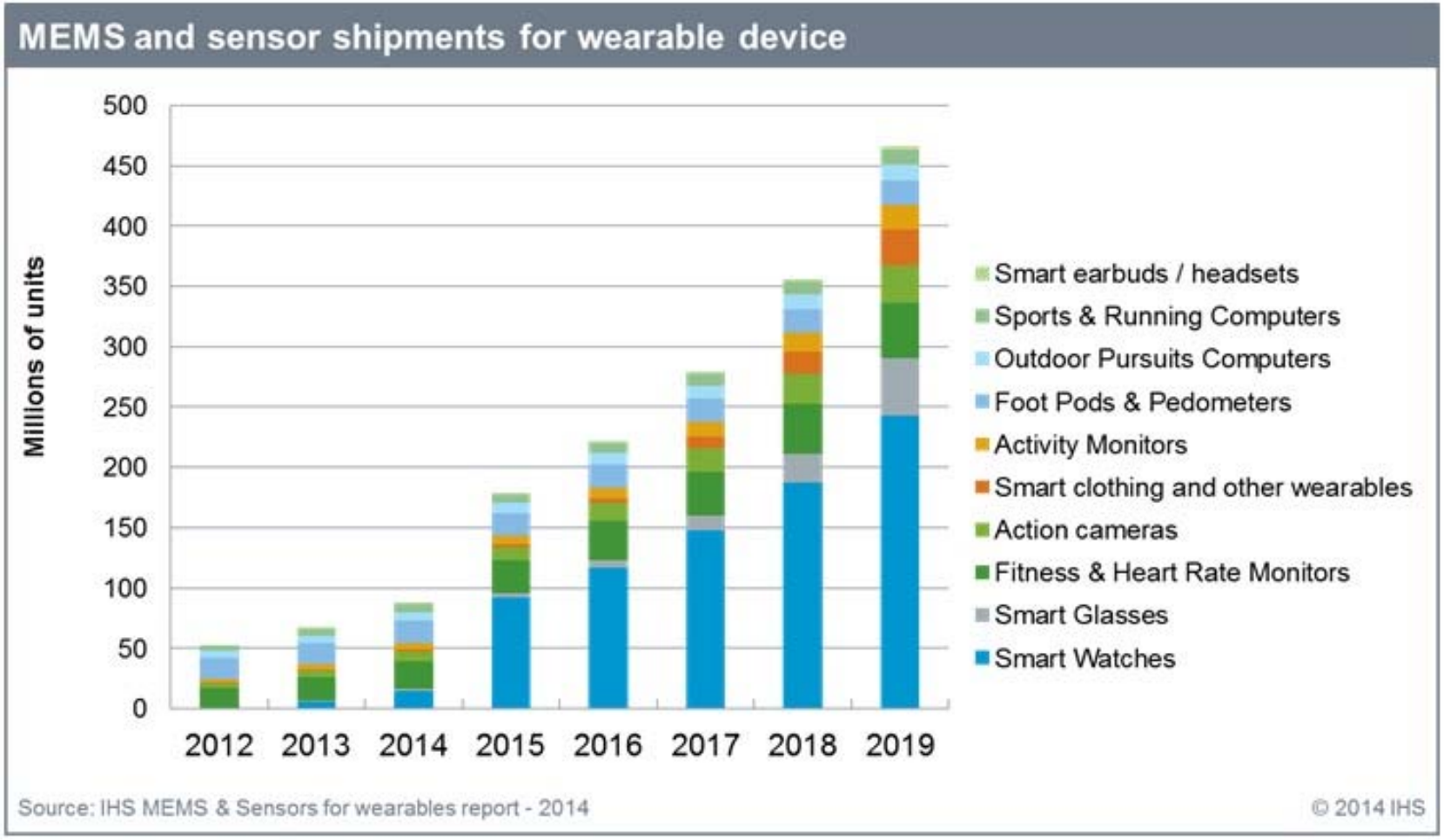


Robotics

Electronic Sensors Markets

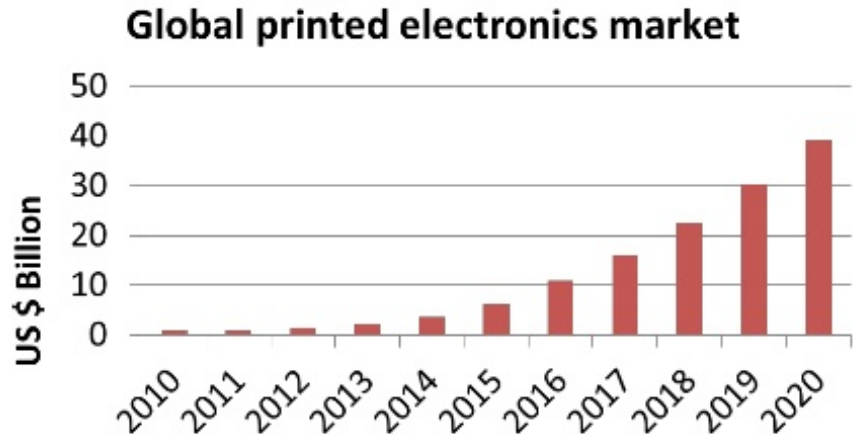


Electronic Sensors Markets



..and emerging electronic fabrication technologies

Global printed electronics market is expected to grow rapidly



End-use applications
- Smart packaging
- Large area sensors
- Active clothing
- Medical devices

RFID labels

Flexible displays

Photovoltaics

Source: Das, R., Harrop, P.IDTechEx- Printed, Organic & Flexible Electronics Forecasts, Players & Opportunities 2010-2020

Analog System Design Issues

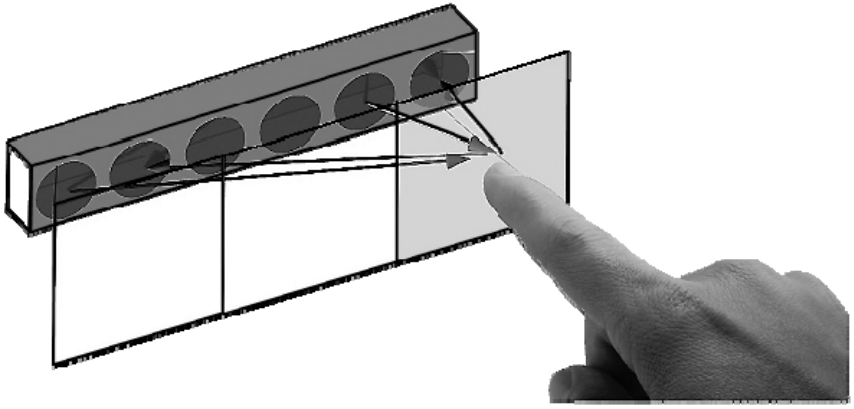
In this context, the design techniques may be all those support items surrounding a data converter, excluding the data converter itself. This includes issues as:

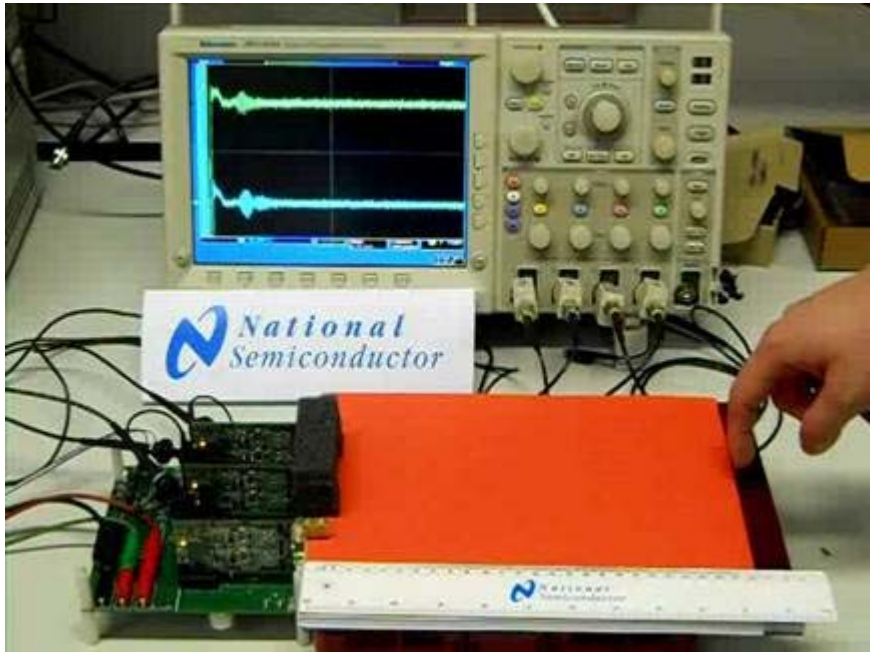
- passive components,
- printed circuit design,
- power supply systems,
- protection of linear devices against overvoltage
- thermal effects,
- EMI/RFI, low voltage /high speed logic interfacing
- Simulation, breadboarding and prototyping.

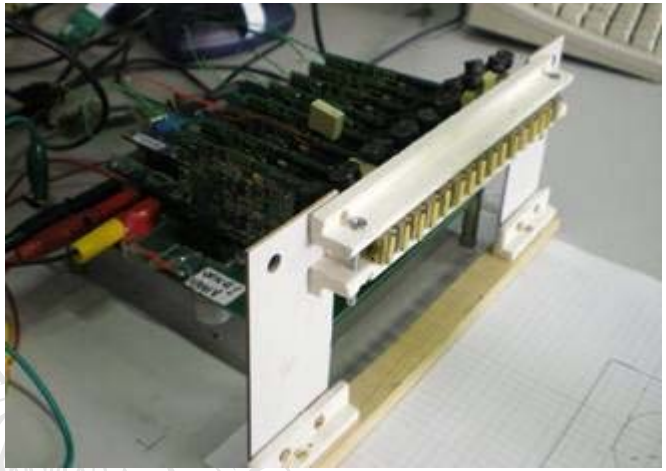
Some of these topics aren't directly involved in the actual signal path of a design, but they are every bit as important as choosing the correct device and surrounding circuit values.
Signal conditioning is such a vital part of data conversion that a considerable amount of discussion is given to topics such as: overvoltage protection, cable driving, shielding, and receiving — where the remote interface is often with op amps and instrumentation amplifiers.

Examples of ultrasonic transducers and analog electronic systems

Target motion / gesture detection



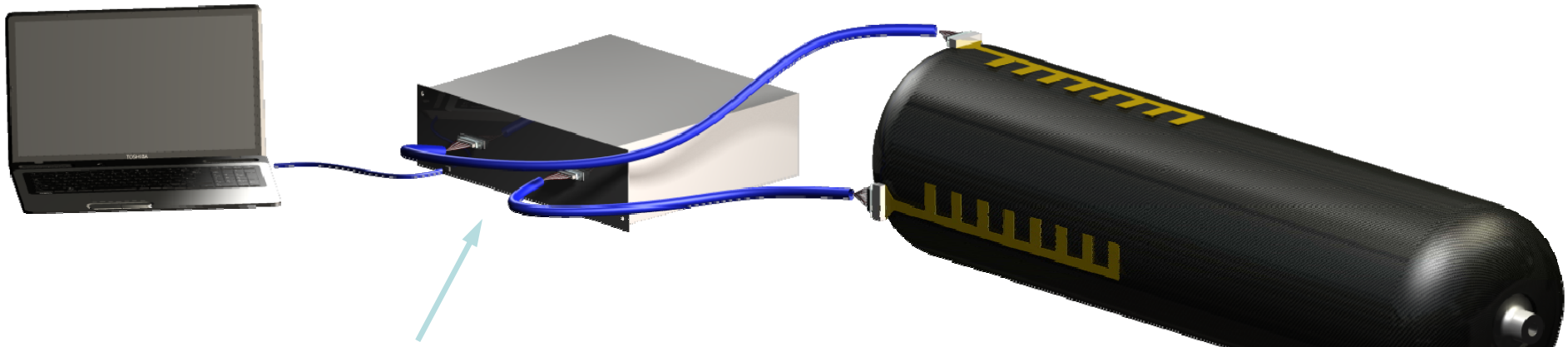


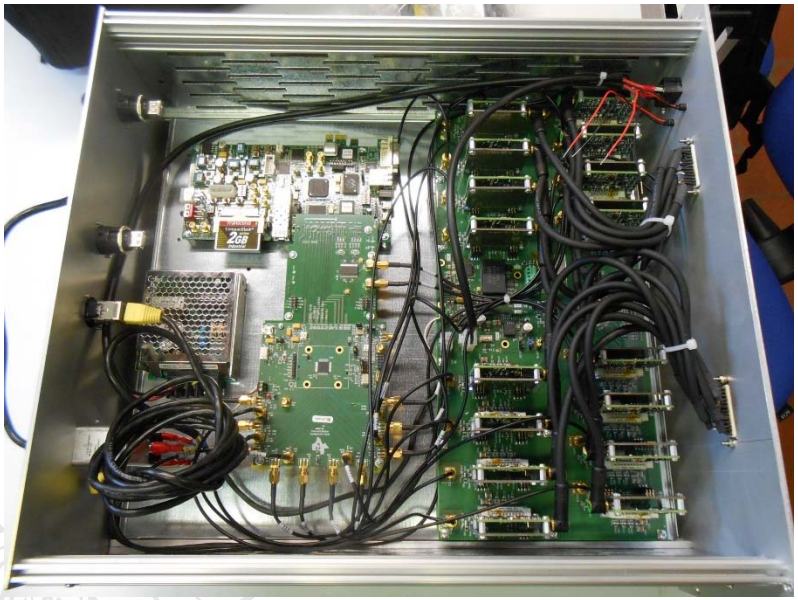


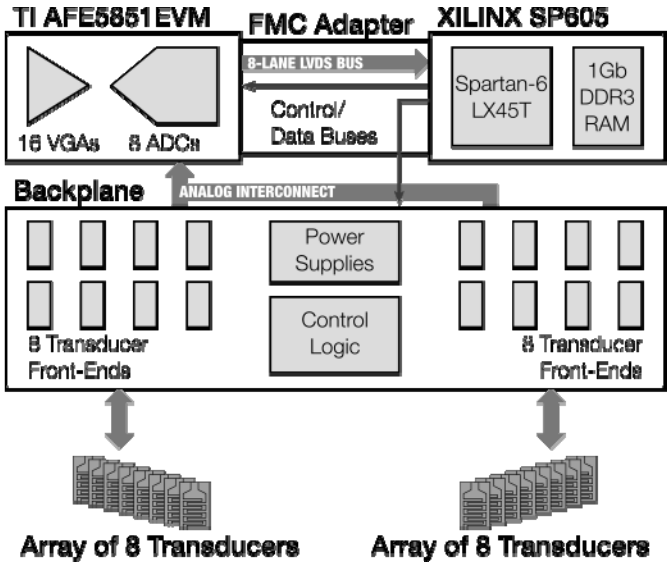
120 kHz – 16 elements ultrasonic transducer array with electronic interface for real time operation

Collaboration with National Semiconductors (till 2011) / Texas Instruments

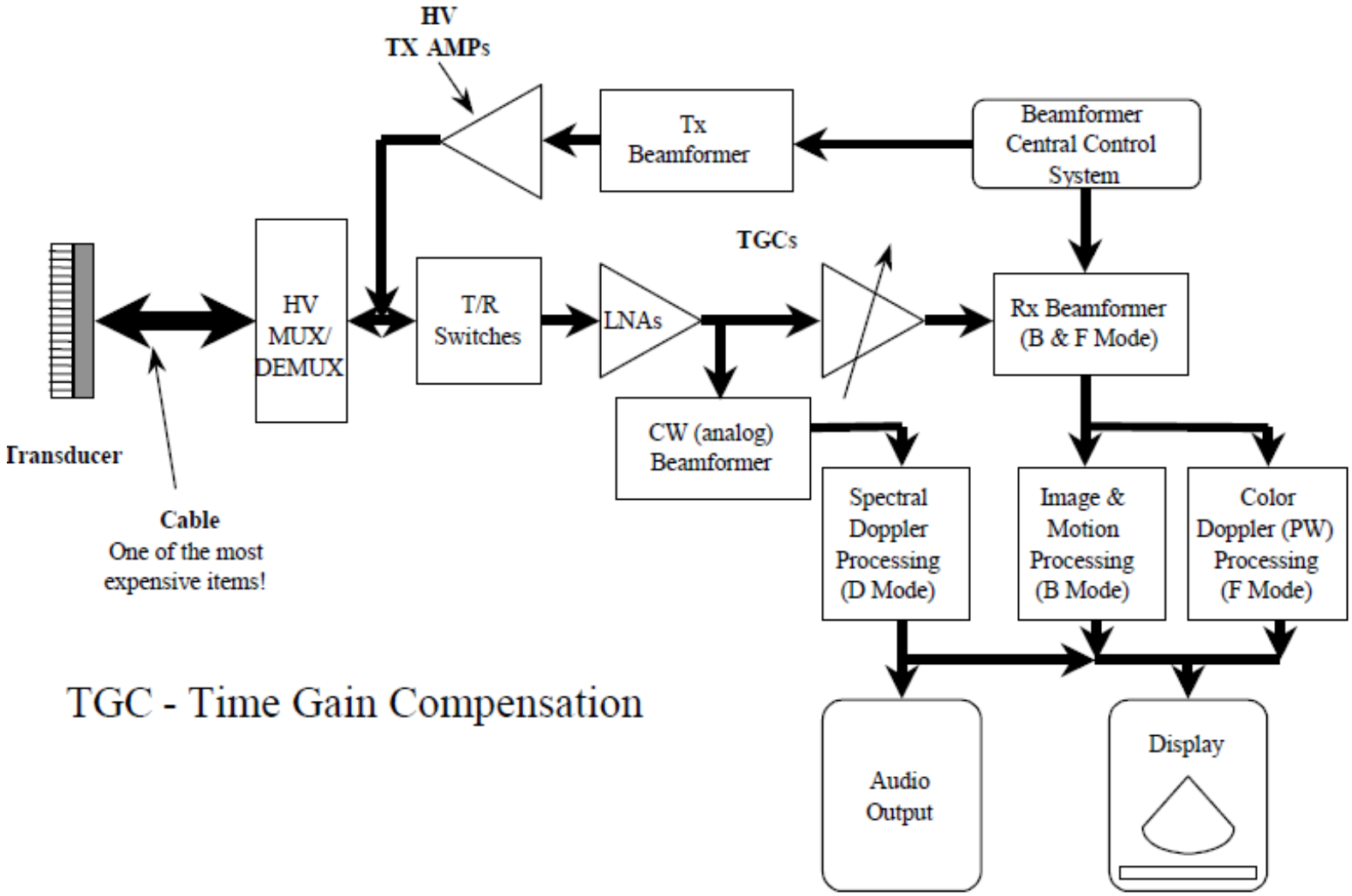
Monitoring of pressure vessels with guided wave ultrasonic transducers (in collaboration with Thales Alenia Space Italia and Texas Instruments)







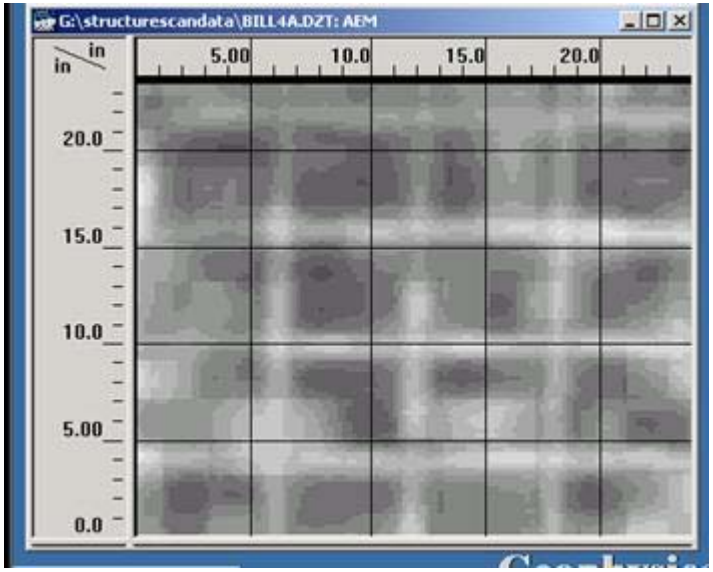
Ultrasonic Echographic System



TGC - Time Gain Compensation

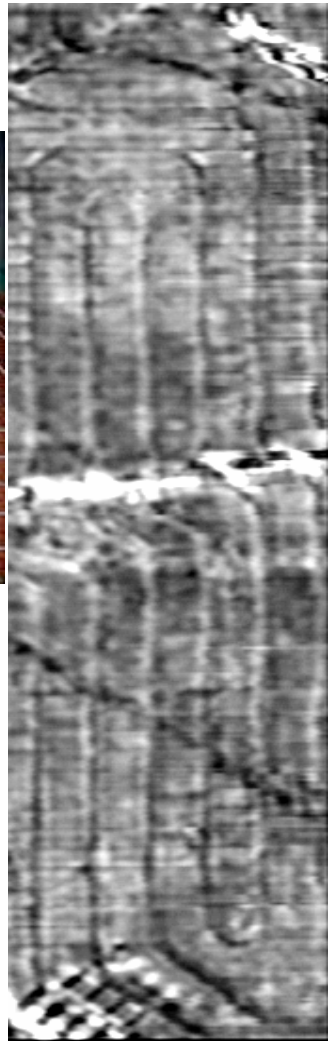
Ground Penetrating Radar and multi-sensor robotic scanner

Ground Penetrating Radar: applications



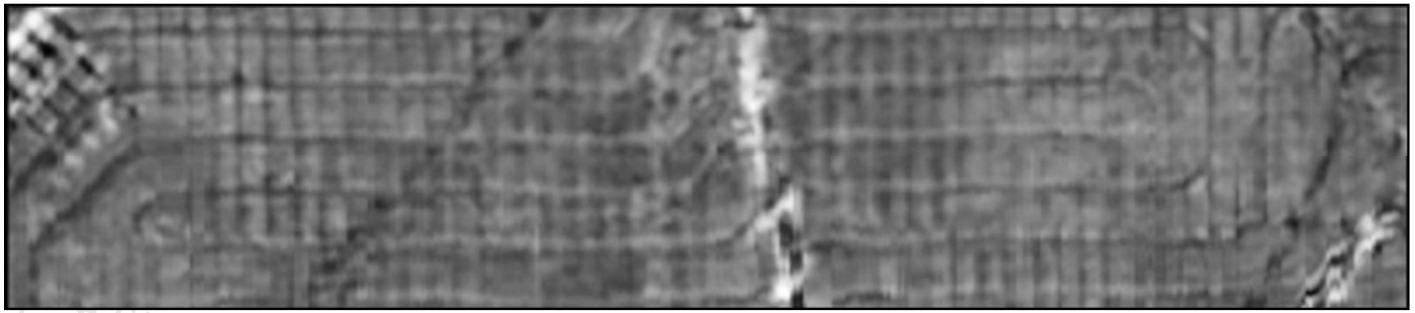
Metal mesh detection into a floor

Central Heating pipes Underneath a *parquet*



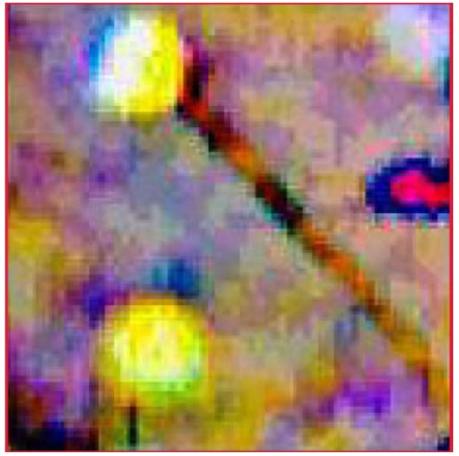
Radar object robotic scanner for high spatial resolution imaging.

Optical and ultrasonic ranging sensors are included in the electronic system for obstacle detection and surface relief recording



High spatial resolution image obtained with a 2 GHz holographic radar with a survey of a floor

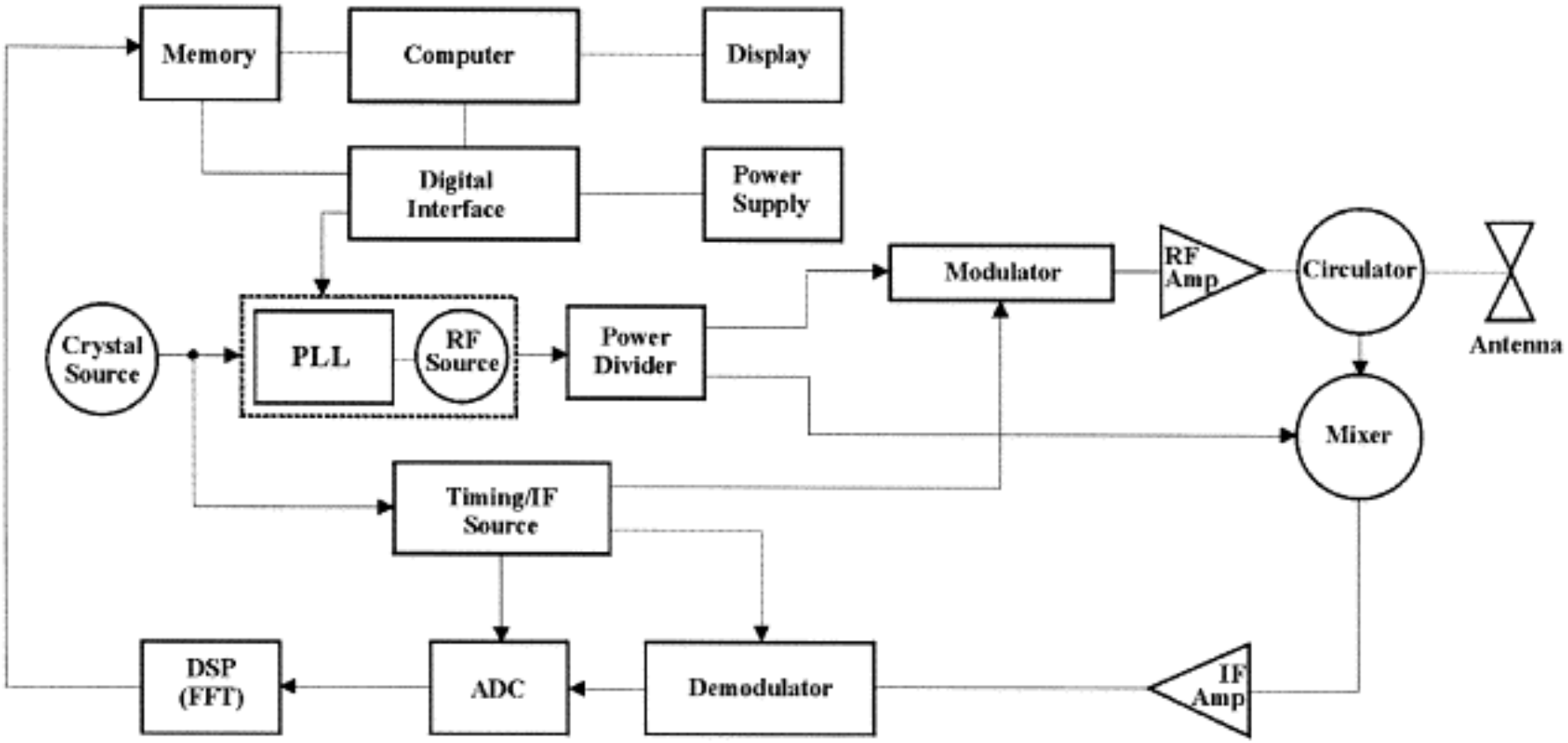
Radar Object Scanner



http://www.scientificamerican.com/blog/post.cfm?id=radar-holography-could-offer-a-safe-2010-07-21

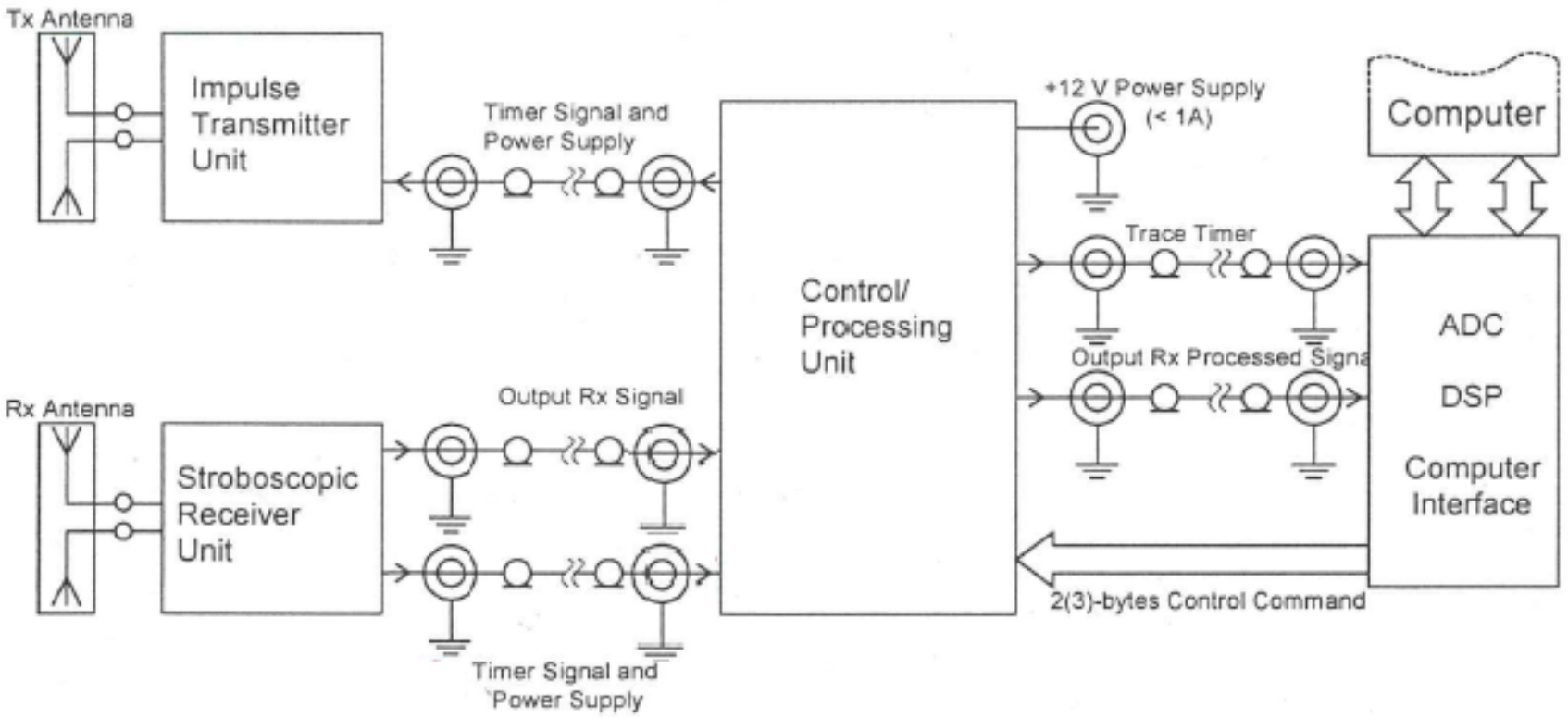
See video at :
http://www.youtube.com/watch?v=G6lM2-Qixyg

Ground Penetrating Radar



Block scheme of a FM / CW radar (narrow band electronics)

Ground Penetrating Radar



Block scheme of a Ultra Wide Band (UWB) radar