

TI HealthTech

Engineering components for life.

TI Solutions for MRI



 **Imaging**

 **TEXAS INSTRUMENTS**

Introduction

- Purpose
 - To show basics of MRI technology and trends
- Objectives
 - To highlight TI's portfolio of non-magnetic packaged components
- Content
 - What is MRI and how does it work?
 - MRI Technology Trends
 - Parallel MRI Imaging
 - Receiver Architecture
 - TI Solutions for Non Magnetic (-NM) Devices
 - References

Highlights:

- What is MRI and how does it work?
- MRI Technology Trends
 - Parallel MRI Imaging
 - Receiver Architecture
- TI Solutions for Non Magnetic (-NM) Devices
- References

Things you have to consider:

- This is not rocket science, **IT IS NUCLEAR SCIENCE**: Magnetic Resonance Imaging (MRI) is a complex technology;
- This is an over-simplified introduction to medical MRI System;
- At the end of the PPT you can find a list of excellent reference, papers and web animation;

What is MRI?

- Medical MRI is a powerful imaging procedure for medical non-invasive diagnosis;
- It combines complex quantum mechanics and computer power to provide high quality images of the body.



MRI Total Body System - Courtesy of Siemens



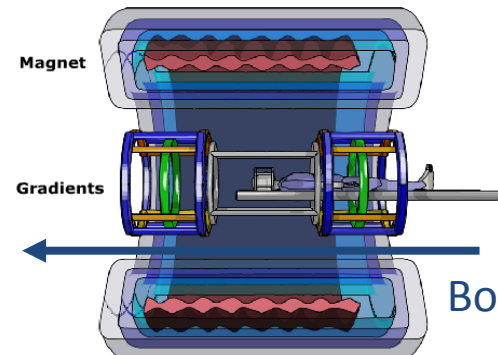
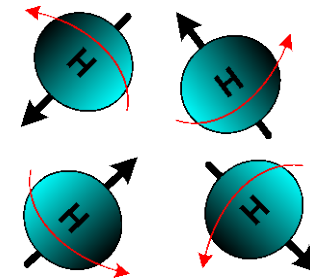
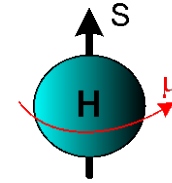
Image of the Human Skull - Courtesy of Volumedic

How MRI works?

- Using strong magnetic fields, MRI induces protons to resonate at RF frequency.
- Since a large portion of the human body is made up of water and fat, and both include hydrogen atoms, the most common MRI machines target the 1H protons.
- This resonance is picked up by one or more tuned antenna (coils), and their outputs are sampled and processed by a data acquisition system.
- Specialized software running on an array of computers reconstructs the processed data into images of the body.

Nuclear Magnetic Resonance: Basic Physics

- Similar to a compass pointer that aligns with the Earth's magnetic field, protons in the body act as small magnets.
- This property is called nuclear "spin" and it is represented by a vector S and a magnetic momentum μ :
- In normal condition the spin directions are randomly distributed, so the net-magnetic momentum M is null.
- When the patient is placed inside the MRI, or into the bore of the magnet, with a large static magnetic field B_0 , the protons align their spin with the B_0 field.



Nuclear Excitation and Relaxation

- If the correct RF electromagnetic energy is applied, some protons will absorb the energy and change from a low to high (excitation) state.
- The excitation signal consists of a complex sequence of radio frequency (RF) pulses, designed to provide the wanted image contrast. They are applied using tuned antenna coils placed in the proximity of the patient
- When the RF pulses cease, the excited protons return to the low-energy state (relaxation) by emitting energy at the same resonance frequency. The MRI receiver receives these relaxation emissions and transforms them into complex digital data for further image processing.

Spatial position and Gradient Field

- To precisely locate the spatial position of the emission, which is necessary to form a 2D or 3D image, the magnetic field strength is varied at different points of the body using the gradient coils.
- By doing so, different locations are subject to different magnetic field strength and the frequency and phase of the emission relate precisely to a specific location of the space

MRI Technology Trends

- Parallel MRI Imaging Systems
- Receiver Architecture
 - Superheterodyne vs Direct Sampling
 - Trend towards Digital Coil

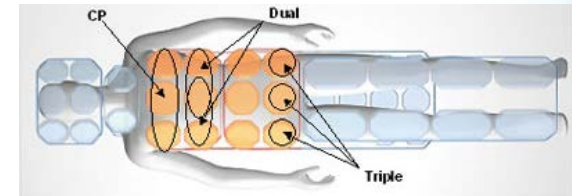
Parallel MRI Imaging Systems

- The amount of data necessary for reconstructing a quality image could be significant and the imaging speed is one important parameter for clinical MRI.
- Scan speed is limited by the time needed for switching the gradient magnetic field, which allow the spatial encoding;
- Instead of relying on increased gradient performance to improve the acquisition time, modern MRI machines use parallel acquisition techniques



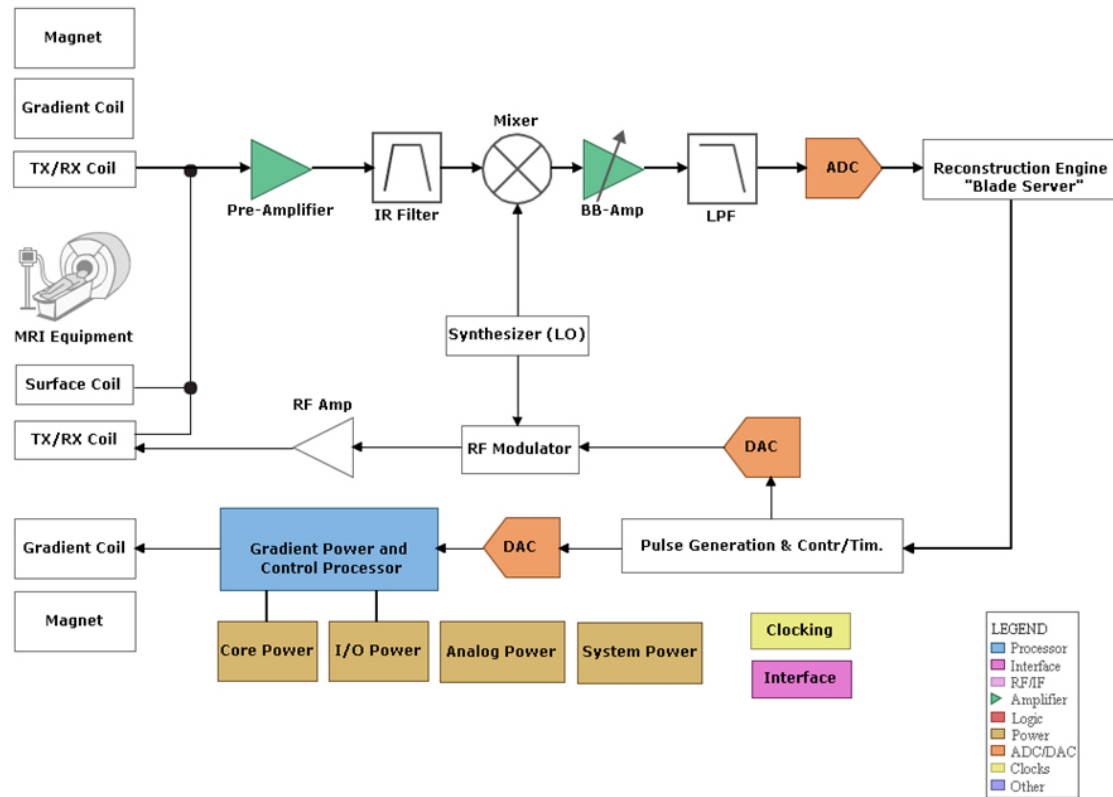
Local antennas are arranged around the patient's body in a phase-array mode. These are often called surface coils.

- Parallel MRI (PMRI) extracts extra spatial information from multiple independent receiver coils in parallel.
- Each surface coil is connected to a dedicated receiver chain where the RF signals are processed in parallel.
- Whole body coils matrix could use up to 76 elements (Torso and whole body).



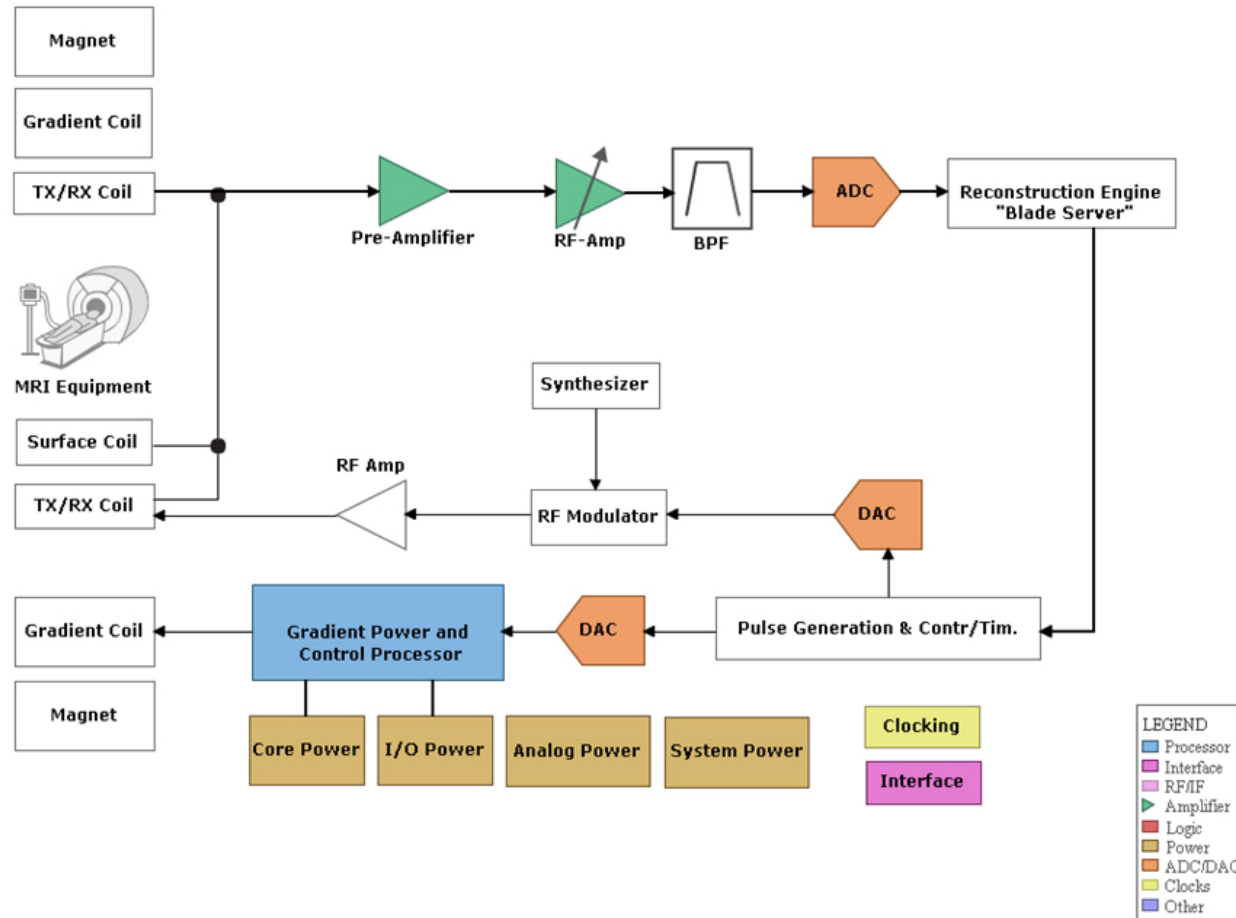
This improves execution-speed, resolution, coverage and image quality.

MRI Superheterodyne Receiver



- Pros:
 - The conversion into digital data occurs at the baseband where the requirements of the ADC sampling frequency and the anti-aliasing filter are more relaxed.
- Cons:
 - To suppress the image noise by at least 40 dB, it uses image rejection filters (SAW or high-order discrete LC resonator) or complex image rejection mixers, which have an impact in the noise performance, in the board space and power consumption.

MRI Direct Sampling Receiver



- Pros:
 - it eliminates the need for analog mixers and image rejection filters, partially reducing the receiver form factor
- Cons:
 - need of high-frequency amplifiers and bandpass filters (BPF) to eliminate signal aliasing

The Industry Trend: Digital Coil

- Moving the receiver electronics closer to the coil area eliminates the need for long and bulky coax cables, running from the pre-amplifier outputs to the receiver inputs.
- Inside the coil area the available volume for the electronics and the ability to dissipate the heat are reduced;
- Any ferromagnetic material in the electronic component introduces an artifact in the image and, therefore...

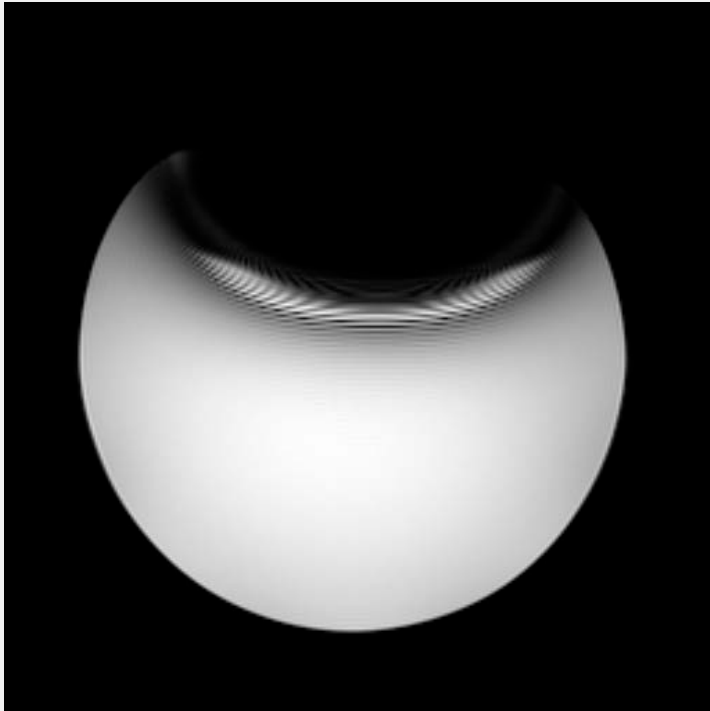
... the components must be non-magnetic.



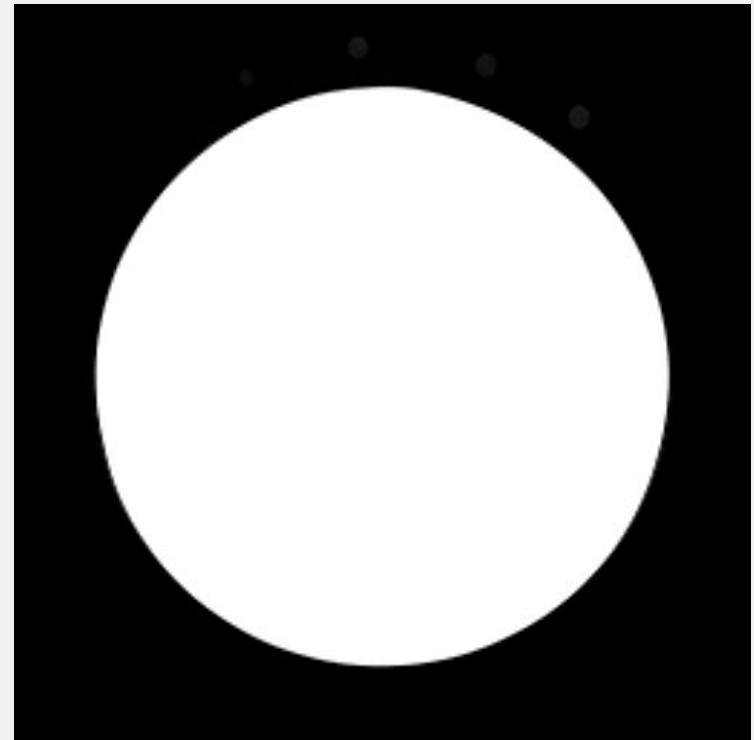
TI Solutions for Non-magnetic Packaging

Image Artifacts due to magnetic material

MRI scan with regular package =
image distortion



MRI scan with
non-magnetic package



Available Non Magnetic Products (-NM)

Pre Amplifier for Coil

- **TL5500RGPT-NM** 1.5T/3T Coil Preamp, QFN 4x4mm, 20 Leads; **RTM**

Analog-Digital Converter

- **ADS5263IRGCT-NM** 16bit/14bit ADC, 100MSPS, BW>130MHz: QFN 9x9mm 64-Leads; **RTM**

Power Management

- **TPS715A01DRBT-NM** 80mA adjustable LDO 1.2V/15V: QFN 3x3mm (DRB 8 leads); **RTM**
- **TLC7701IDRBT-NM** Micro Power Supply Voltage Supervisor, QFN 3x3mm (DRB 8 leads); **Sample available**

Analog Switch

- **TS5A22362DRCT-NM** 0.65ohm DUAL SPDT ANALOG SWITCH, QFN 3x3mm (DRC 10 Leads) **RTM**

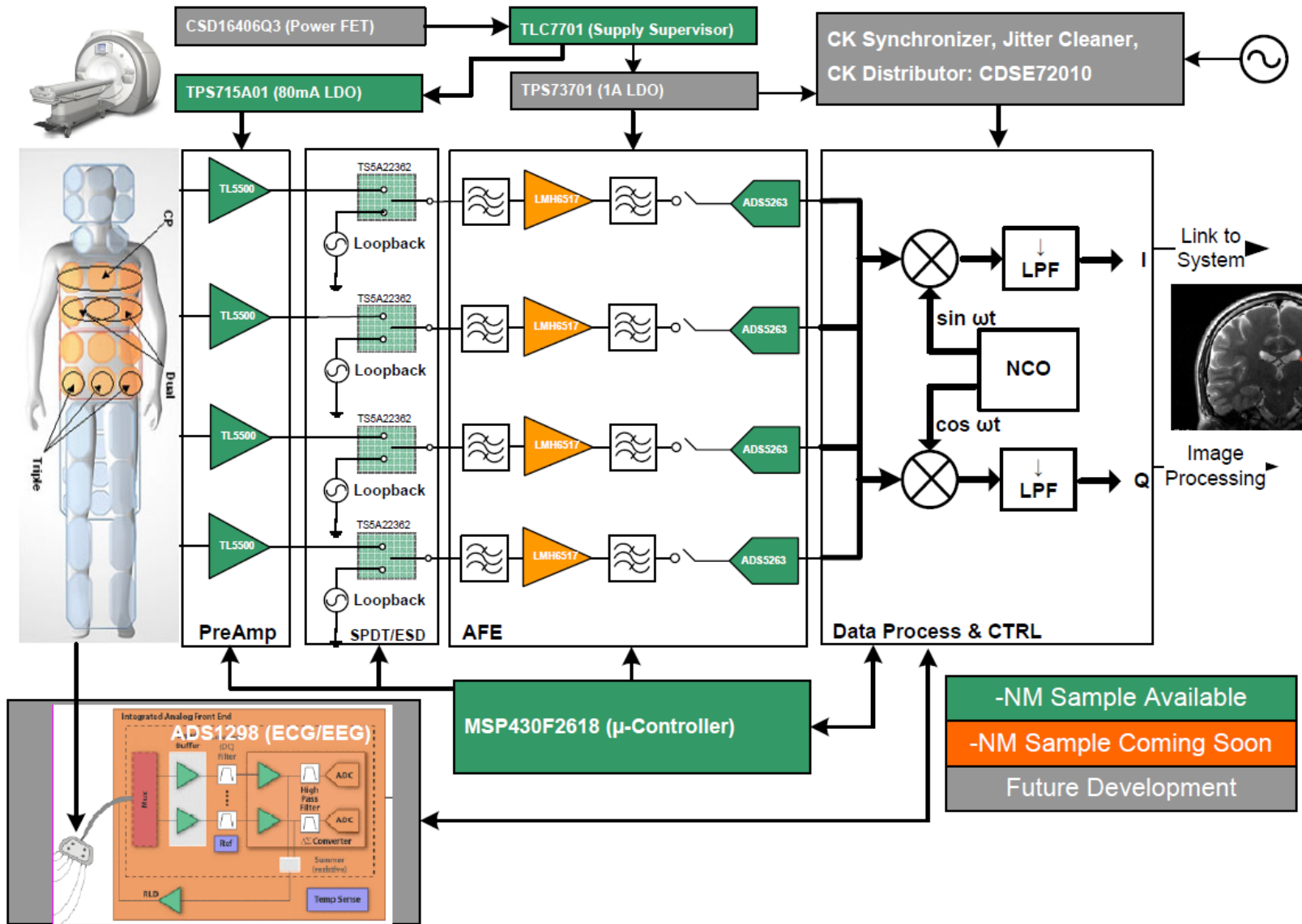
15KV ESD Diodes

- **TPD2E001DRST-NM** 5V Double IO Low Cap IEC ESD Diodes, QFN 3x3 (DRS 6-Leads) **RTM**

Microcontroller

- **MSP430F2618TPMT-NM** Ultra-low-power microcontrollers 64-LQFP 12x12mm PM (S-PQFP-G64) **Sample available**

MRI Receiver with Non-Magnetic (-NM) TI parts



ADS5263:

4 Channel, 14/16 Bit, 100MSPS ADC

ADC for Medical
Imaging
ADS5263



Features

- Quad-Channel, 16-Bit, High-SNR Mode
 - 85-dBFS SNR, 380 mW/ch
- Quad-Channel, 14-Bit, Low-Power Mode
 - 74-dBFS SNR, 195 mW/ch
- Full Scale Input Range: 4Vpp (16-bit), 2Vpp (14-bit)
- Programmable Digital Gain: 0 to 12 dB
- Integrated Digital Functions
 - Channel Averaging
 - Digital Gain
 - Decimation filter
- Non-magnetic packaging

Benefits

- Dynamic ability to switch between High-SNR mode and Low-Power mode for optimization between best image quality and power constrained systems.
- Non-magnetic package option allows for operation in a strong magnetic field without image distortion.

Applications

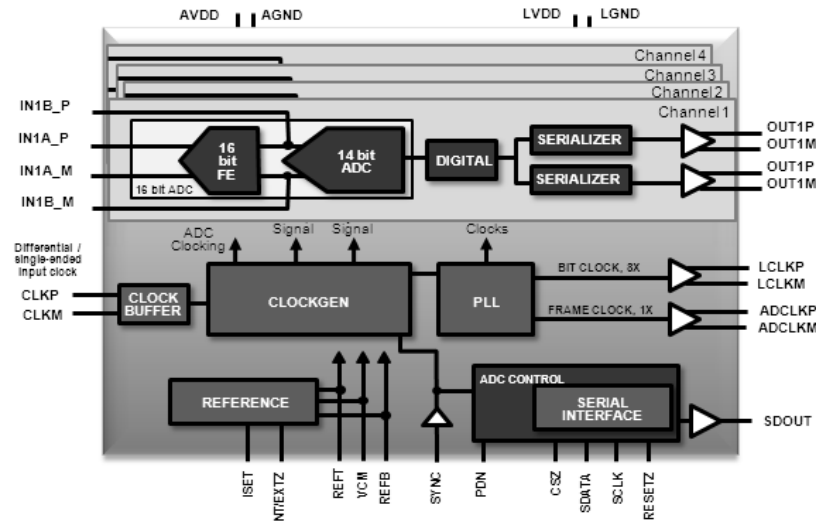
- MRI
- Spectroscopy
- CCD sensor based imaging systems
- High speed communication applications

Samples: Now

EVM: Now

Production: Released

Package: 9-mm × 9-mm 64-Pin QFN



Tutorial References

- www.e-mri.org
- <http://www.cis.rit.edu/htbooks/mri/>
- <http://www.nlm.nih.gov/medlineplus/tutorials/mri/htm/index.htm>
- <http://www.mri-tutorial.com/>
- http://users.fmrib.ox.ac.uk/~stuart/thesis/chapter_2/contents.html

Summary

- Moving electronic components closer to MRI coil area has benefits, but can create magnetic interference in the image results.
- To avoid this interference, any electronic components used must be in special non-magnetic packaging.
- TI HealthTech has a portfolio of products for MRI applications that are available in non-magnetic packaging.
- To learn more please visit www.ti.com/healthtech