Ethernet Camera Software Solution

FTF-AUT-F0307

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Session Introduction

• Jan Perny
  – System Application Engineer, Embedded Software Developer
  – AISG Automotive Software Team in Roznov pod Radhostem, Czech Republic

• Ethernet parking camera (one or more for surround view)

• Freescale offers the right solution that will save you money
  – the right microcontroller
  – the right software
Session Objectives

After completing this session, you will be able to:

• Articulate parking camera problems and solutions

• Explain why the MPC5604E is the right device for audio/video data streaming over the Ethernet

• Understand software key features

• Save money
Agenda

• Introduction
• The Right Chip
• The Right Software
  – Ethernet Camera Application Package
  – Ethernet Streaming Software Package
  – Application Architecture
• Demo
• Questions & Answers
Problems to be Solved

• **Timing** is the crucial point for video over Ethernet applications such as parking camera

• **Low Latency**
  - Delay between the picture taking and showing it on the screen
  - Delay between pictures of the same situation taken by different cameras

• **Synchronization** – Only pictures taken at the same time by different cameras should be combined in the resulting image

• **Price** – Provided solution must be less expensive than existing ones

• **TCP/IP stack** is *not* the best solution
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The Right Chip – MPC5604E

• Specifications
  - 64 MHz Qorivva e200 zen0h core

• Memory
  - 512k byte program flash with ECC
  - 4x16k byte data flash with ECC
  - 96k byte SRAM with ECC

• I/O
  - FlexCAN, LINFlex
  - 5V ADC

• System
  - 3.3V single supply
  - 64 pin LQFP package
The Right Chip – Important Features

- **MJPEG Video Encoder**
  - Image sensor interface supporting up to 1.2MPixel
  - YUV422 or ITU656 input format on parallel data interface (PDI)
  - Baseline/extended sequential ISO/IEC 10918-1 JPEG encoder (8/12 bit)
  - Motion JPEG (MJPEG), no buffer needed for pictures prediction algorithms (no latency is introduced)
  - 8 kB data buffer (one JPEG image consumes approximately 400 kB)

- **Fast Ethernet Controller (FEC)**
  - Proven 10/100 Mbit/s Ethernet Controller with DMA capability

- **IEEE 1588 Precision Time Protocol (PTP) Support**
  - Precise time counter with adjustable counting rate
  - Ethernet frames time-stamping based on frame headers parsing
The Right Chip – Hardware Design

Just MPC5604E and little more is needed for the complete solution:

- PDI compatible camera
- Ethernet physical layer driver (PHY)
  - BroadRReach PHY connected via MII
  - Allows full duplex 100 Mbit/s throughput over a single twisted pair cable – significant solution cost reduction
- Crystal oscillator and power supply circuitry

(Note: Camera dimensions are 4 x 4 cm)
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The Right Software

- **Ethernet Camera Application Package**
  - Camera and MJPEG encoder drivers, control algorithms
  - Handling all video related stuff and dealing with the video data buffer

- **Ethernet Streaming Software Package**
  - Ethernet driver, time synchronization, stream builders
  - Alternative uses such as Ethernet Audio Amplifier (audio streaming)

- **Freescale AUTOSAR OS for MPC5604E**
  - Runtime OS with well known parameters
  - Statically configurable
  - Conforms to AUTOSAR standard
The Right Software

• All software modules optimized for minimum core load

• All software packages are:
  − Developed using Freescale’s automotive SPICE level 3 process
  − Licensable as a software product from Freescale

• Easy integration with Freescale AUTOSAR OS for MPC5604E
(Note: AUTOSAR OS and supporting modules are not depicted.)
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Ethercam – Ethernet Camera Application

- Ethercam
  - Control Algo
  - Video Encoder
- I2C
- MPEG Encoder
- I2C

TCP/IP Stack
- AVB Stream Builder
- FEC Driver

PTP Stack
- PTP Interface
- 1588 Support

TCP/IP Stack Interface

PTP Interface
Ethercam – Ethernet Camera Application

• Task controlling the rest of sub modules

• API for application upper layer
  – Camera start/stop
  – Configuration data upload and configuration change during runtime
ICTR and I2C – Ethernet Camera Application

Application

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ICTR
- Control Algo
- Video Encoder
- JPEG Encoder
- MJPEG Encoder
ICTR and I2C – Ethernet Camera Application

• I2C driver and communication protocol implementation

• Configuration of Omnivision and other cameras
  – Initial configuration
  – Configuration changes during runtime
    ▪ Access to all camera registers

• Support for other vision sensors planned
JPEG Encoder – Ethernet Camera Application

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JPEG Encoder – Ethernet Camera Application

• Low level driver for MJPEG encoder hardware module

• Configures MJPEG encoder hardware module

• Provides basic functions:
  - Interrupts handling
  - Errors handling
  - JPEG quality control
  - Start/stop
# Video Encoder – Ethernet Camera Application

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Video Encoder – Ethernet Camera Application

• Video data buffers management
  – MJPEG internal buffer DMA handling
  – Dividing data into packages transferable over Ethernet

• JPEG quality and output data rate control

• Interrupt handlers
Control Algo – Ethernet Camera Application

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TCP/IP Stack

| AVB Stream Builder |
| TCP/IP Stack Interface |
| FEC Driver |
| FEC |
| 1588 Support |

PTP Stack

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PTP Support
Control Algo – Ethernet Camera Application

- Algorithms for output data rate and JPEG quality control
  - Prevents data buffer overflow by changing image quality thus reducing and increasing number of bytes per image
  - Configurable bandwidth limitations
## Supporting Modules – Ethernet Camera Application

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Supporting Modules – Ethernet Camera Application

• **STREAM_IF**
  - Hides differences between stream builders
  - Stream builder can be chosen by single configuration parameter

• **OS_DEP**
  - Wraps operating system (OS) API, allowing integration with different operating systems
  - Prepared to be integrated with Freescale AUTOSAR OS

• **Sensor Interface**
  - Driver for camera RESET and POWER DOWN inputs via GPIO
Agenda

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• Demo
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## AVB Stream Builder – Ethernet Streaming SW

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### AVB Stream Builder

- **TCP/IP Stack Interface**
- **PTP Interface**

### FEC Driver

- **1588 Support**
AVB Stream Builder – Ethernet Streaming SW

• Builds AVB stream from raw video packets

• Designed according to IEEE 1722
  – Presentation time-stamps when to show picture
  – Support of multiple simultaneous streams

• No data copy

• Optimized for speed
UDP Stream Builder – Ethernet Streaming SW

• Alternative to AVB Stream Builder

• Bypassing TCP/IP stack to ensure low delays

• Simple internal ARP module

• Used for development purposes
  – Stream can be played with VLC player on computer

• Does not support time-stamping
FEC Driver – Ethernet Streaming SW

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FEC Driver
FEC Driver – Ethernet Streaming SW

• Low level driver for FEC

• Allows multiple upper stacks accessing controller (PTP, TCP/IP, AVB)
  - Supports limitation of used buffers for each stack – bandwidth limitation

• Zero Copy
  - MCU core does not copy data from memory to transmit buffer or from receive buffer to memory
  - FEC DMA is used to gather transmitted data
  - Receive buffer memory can be exchanged for another one
  - Receive buffer may be locked and driver will not use it
PTP Interface – Ethernet Streaming SW

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PTP Interface

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PTP Interface – Ethernet Streaming SW

• Low level driver for IEEE1588 support hardware module
  - Configures/adjusts precision time counter as requested by PTP stack
    (Speed up, slow down, set the value)
  - Gathers frame reception and transmission time-stamps to allow PTP stack to measure network delay
  - Passes PTP frames from PTP stack to FEC driver and vice versa

• Designed according to IEEE1588

• Prepared to be integrated with IXXAT PTP stack
## TCP/IP Stack Interface – Ethernet Streaming SW

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TCP/IP Stack Interface – Ethernet Streaming SW

• Separate path for camera control messages with low priority
  – Limitation of FEC driver buffers utilized by TCP/IP stack to prevent delay of streamed data
  – No data copy

• Prepared to be integrated with Elektrobit TCP/IP stack
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Right Software – Architecture

Application

Control & Status Messages

Control Algo

I2C

ICTR

Video Encoder

FEC Driver

FEC

1588 Support

IC

Video data

Video packets

Time

Time-stamps

AVB Stream Builder

TCP/IP Stack Interface

TCP/IP Stack

PTP Interface

PTP Frames

Monitoring & control

Quality

Camera configuration data

I2C

JPEG Encoder

MJPEG Encoder

AVB Stream
Summary

• Freescale provides Ethernet streaming software package that is convenient for many audio or video streaming applications

• Freescale provides Ethernet camera software package that implements video streaming function

• Solution cost can be reduced using right software and right Ethernet PHY

• Timing and synchronization are crucial for the Ethernet parking camera

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