

## Introduction



The logiSTEP is a stepper motor controller IP core from Xylon logicBRICKS IP cores library. It enables simultaneous control of 1 to 16 two-phase stepper motors and supports different control methods: full-step, half-step and microstepping. Supported motor types are MMT and Switec. The logiSTEP is being primarily designed for the Xilinx® SoC and FPGA devices.

Hardware implemented acceleration/deceleration/smoothing algorithms, embedded into the logiSTEP, enable precise and smooth motors control. The logiSTEP is, like the other logicBRICKS IP cores fully embedded into Xilinx Vivado® and ISE® Design Suits.

In order to demonstrate possible logiSTEP application use, this application note includes parts of the User's Manual of the logiHAC Automotive Hybrid Cluster Development Platform, which is initially designed by Xylon in 2009. The automotive instrument cluster presents a typical IP core's application case, but the logiSTEP can be used in other applications as well.

The logiSTEP is available directly from Xylon under the terms of the Xylon's IP License. Please visit our web shop or contact Xylon for pricing and additional information:

Email: [sales@logicbricks.com](mailto:sales@logicbricks.com)  
URL: [www.logicbricks.com](http://www.logicbricks.com)

## Revision History

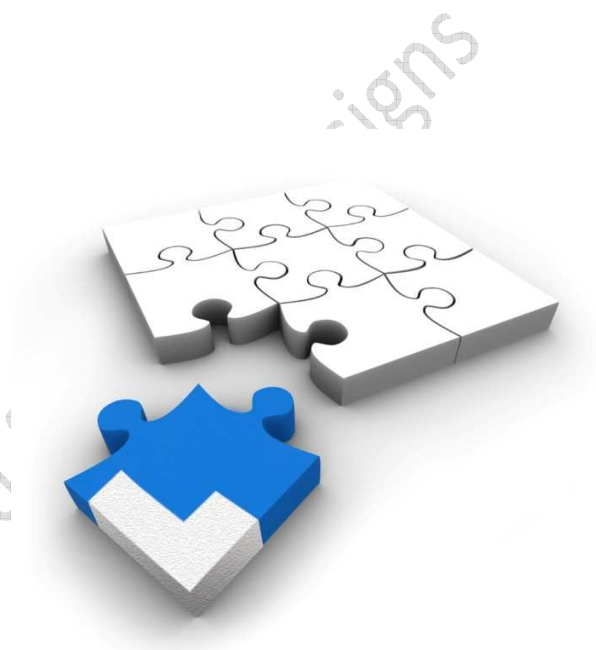
Version	Date	Author	Approved by	Note
1.00.a	11.9.2014.	G. Galic		Initial Xylon release

# logiHAC

## *User's Manual*

**Version: 3.00.c**

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## 1 Getting Started

### 1.1 Introduction

An automotive instrument cluster is a central part of the car dashboard that powers and controls video displays, LED warning lights, analogue gauges, sound signals and stepper motor zero-positioning. The cluster communicates with other car subsystems, and collects and processes the acquired data. A car driver gets the processed data.

This document briefly describes the Xylon/Xilinx Hybrid Advanced Cluster (logiHAC) + Head-up Display (HUD) system based on Xylon logiCRAFT6 Compact Multimedia Display Development Platform. The logiHAC is an example car hybrid cluster combining a reconfigurable high-resolution LCD display with electromechanical gauges driven by purpose specific stepper motors.



Figure 1: The Cluster Demo System

## 2 logiHAC+HUD Hardware - Functional Overview

### 2.1 Features

The logiHAC Development Kit hardware platform is packed into a single Plexiglas casing comprising the Xylon logiCRAFT6 board and a high resolution color LCD display. logiHAC utilizes a subset of logiCRAFT6 features:

- Xilinx Spartan-6 XC6SLX45T device
- 7" 800x480 LCD color display
- 2 x 128 MB DDR2 SDRAM memory
- 2 x 8 MB SPI Multi I/O flash memory
- 2 GB SD-Card Flash memory
- 2 video inputs selectable from 4 CVBS or 2 S-Video inputs
- LVDS output channel from the FPGA (LCD interface)
- Power and control output for CCFL backlight inverters and LCD backlights available on board
- RS-232 interface

The feature set is additionally expanded by add-on boards. The cluster CRFC03 add-on board features:

- Microchip PIC18F2680 MCU
- TTL drivers for 4 stepper motors
- 4 Switec X25589 stepper motors
- Analogue electronics for the Zero Position Detection (zero pointers positioning)
- Expansion connectors
- CAN driver

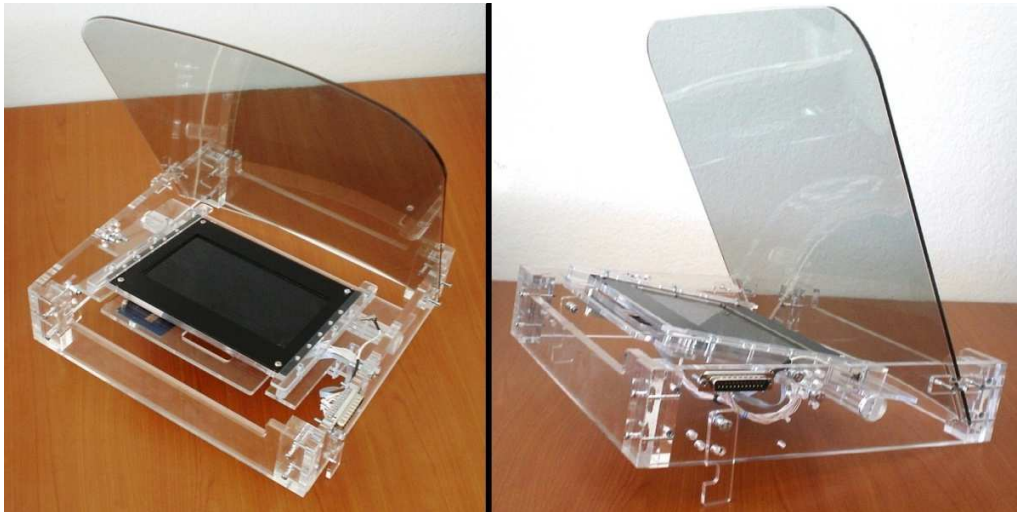
The HUD demo hardware platform is packed into a single Plexiglas casing comprising the high resolution color LCD display, windshield and backlight driver board.

The logiHAC+HUD Kit includes an FPGA reference design that is based on the Xilinx MicroBlaze™ soft-CPU acting as a microcontroller (MCU) controlling all system functions. The reference design can be changed by user, so the user can make different variations of the design. The cluster users can use this platform for different in-house developments.

## **2.2 The HUD demo box assembly**

The Figure 2 figure demonstrates physical assembly of the HUD Development Kit. All Kits HW parts are packed into a single Plexiglas casing that has a shape of a square. The HUD demo includes:

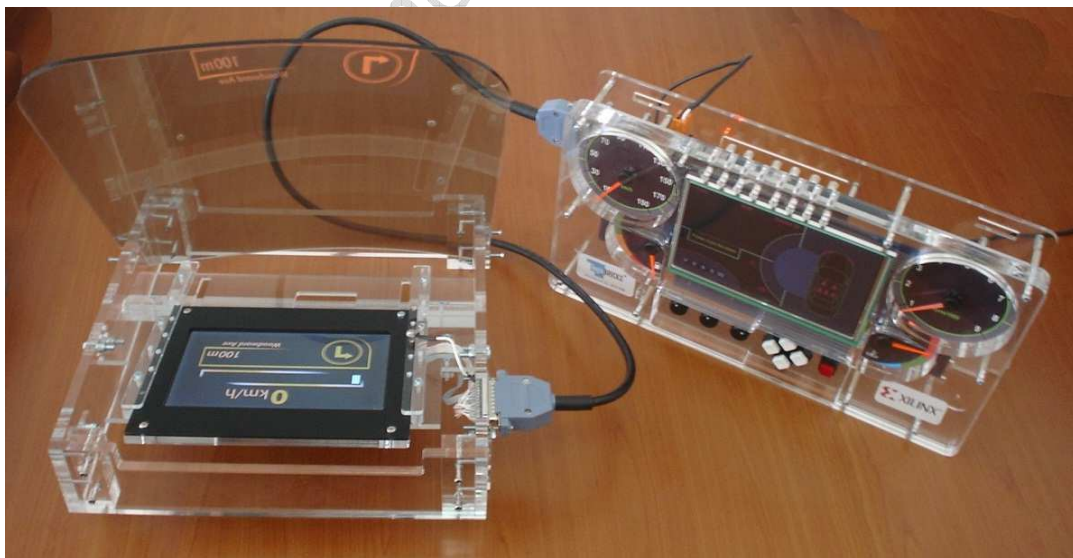
- Plexiglas casing
- 7" 800x480 LCD color display
- Plexiglas windshield
- Backlight driver board
- DB-25 connector



**Figure 2: logiHUD Assembly**

## 2.3 logiHAC and HUD connection

The logiHAC and HUD demos are connected through the shielded cable with the DB-25 connectors on its ends. For this purpose, the corresponding DB-25 connector is attached to the logiHAC Plexiglas casing. On the logiHAC side it is wired to the logiCRAFT6 expansion connector connecting HUD demo with the Xilinx Spartan-6 FPGA device.



**Figure 3: logiHAC and HUD connection**



### 3 logiCRAFT6 Compact Multimedia Platform

The logiCRAFT6 is a Compact Multimedia Display Development Platform for various electronics markets. The platform combines Xilinx Spartan-6 FPGA with the Xylon logicBRICKS™ IP cores library.

The logiCRAFT6 is based on older, Xylon development platform – the logiCRAFT3. Its small form factor is intended to retrofit a 7" LCD, targeting single and remote display applications.

The logiCRAFT6 platform is primarily aimed at the automotive market, including applications such as navigation, infotainment, rear-seat entertainment (RSE), and driver assistance. Other multimedia applications are equally applicable, such as consumer, medical, and measurement instrumentation or factory automation applications.

The logiCRAFT6 platform:

- Supports a wide variety of simultaneous video input and output standards, such as CVBS or S-Video input supporting PAL/NTSC, and LVDS, DVI or VGA video output.
- Provides Audio input and output capabilities.
- Enables connectivity via CAN, LIN and RS232. It can be optionally extended with an Apple iPod compatible serial interface, as well as a Bluetooth module based on Cambridge Silicon Radio.
- Provides 4 LVDS camera input capabilities, suitable for surround vision.
- Offers optional controls for touch screen capability.



**Figure 4: The logiCRAFT6 board**

### 3.1 Block Diagram

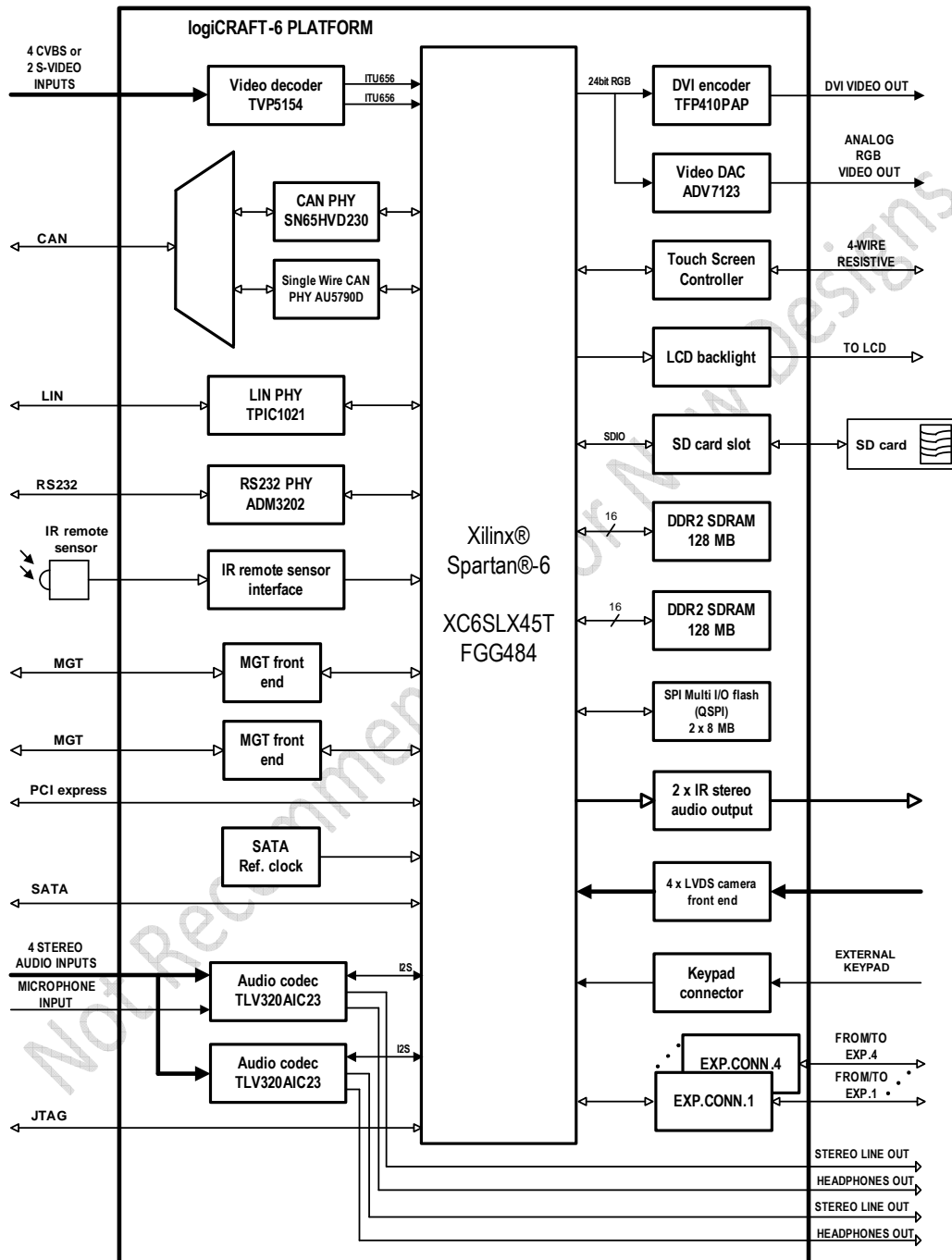


Figure 5: The logiCRAFT6 Block Diagram

## 4 Cluster Add-On Boards CRFC03

The CRFC03 Add-On Board has been primarily designed for the logiHAC.

It plugs into logiCRAFT3 expansion ports and busses the SPI interface, ADC control lines and stepper motor controller's outputs.

High-strength current drivers (74ACT244) for direct stepper motors driving are mounted on the CRFC03 along with stepper motors.

The board also supports 1 CAN bus interface currently used by the logiHAC.



Figure 6: Add-On CRFC03 (top and bottom view)

The logiHAC PCB board is delivered with jumpers already set in default positions. User does not have to make any adjustments prior to the first platform's start. Adjustments of jumpers, as well as other platform's adjustments and features, are described within this document.



## 4.2 The FPGA-PIC Interface

The Serial Peripheral Interface (SPI) is used for a synchronous serial communication between the PIC microcontroller and the FPGA. The PIC is the SPI master while the FPGA implements SPI slave. The PIC handles demo's user interface and sends data to a FPGA. The FPGA implemented MicroBlaze CPU collects data received from PIC and uses it in a running cluster software application.

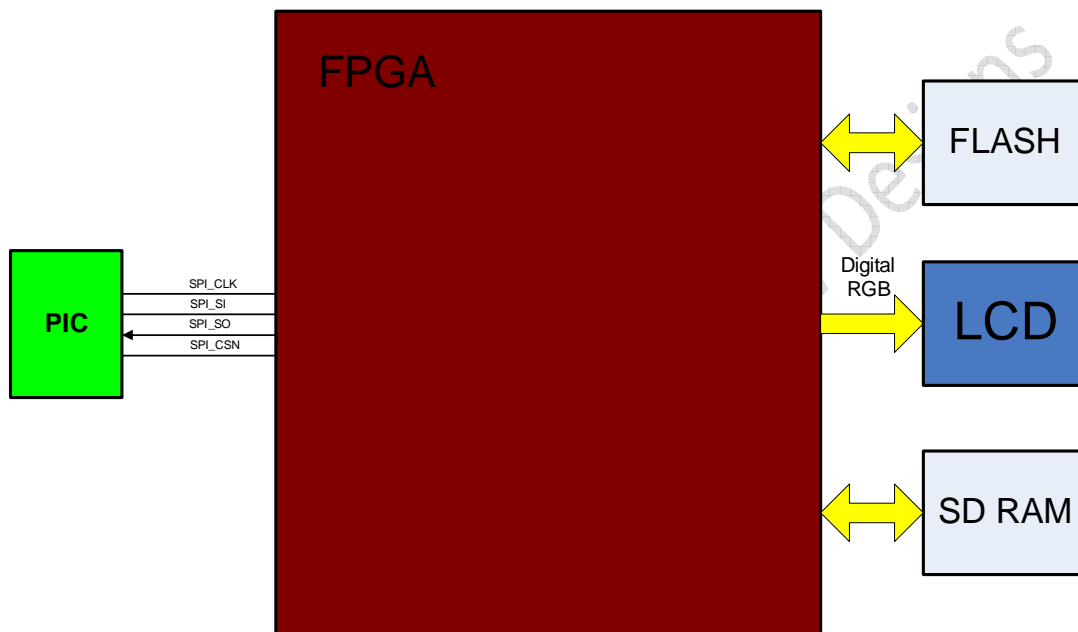


Figure 7: SPI Interface connecting FPGA and PIC

## 4.3 Stepper Motor Drivers

The CRFC03 add-on board features 2x 74ACT244 octal bus buffers with 3-state outputs. The device allow data transmission from the A bus to the Y bus. One 74ACT244 device is used for an independent driving of 2 stepper motors at once. These devices are capable to source enough current for stepper motors powered by 5VDC.

Besides the current strength issue, these drivers also serve as voltage levels translators. They are translating 3.3VDC Xilinx FPGA outputs (logiSTEP IP outputs) to 5V driving signals enabling better moments on motor's shafts.

Figure 8 shows that the first 4 inputs/outputs and the last 4 inputs/outputs are being separately controlled by the 1G and 2G outputs enable pins. Three-stating of drivers' outputs is being used during the Zero Position Detection procedure.

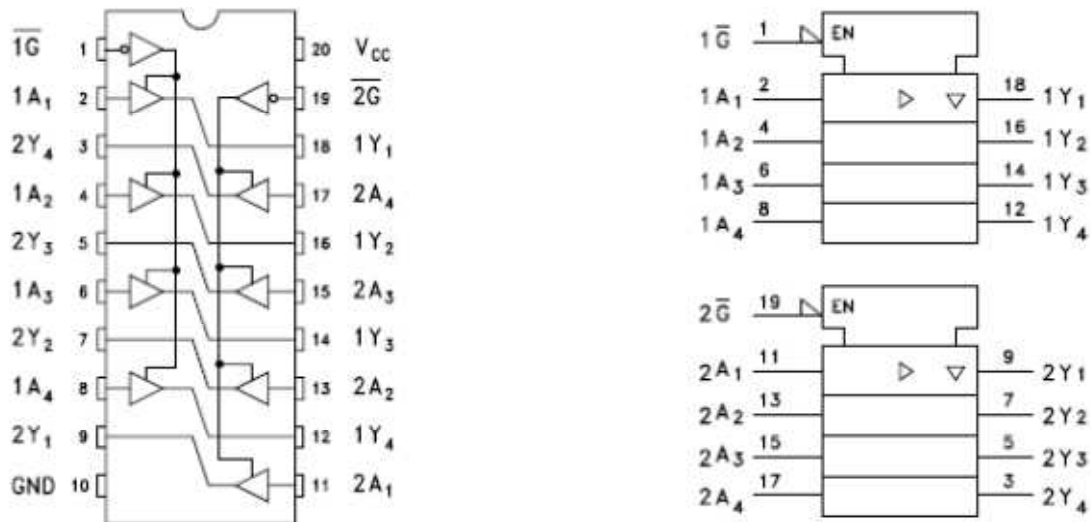


Figure 8: 74ACT244 drivers

#### 4.4 Deserializer

The CRFC03 board uses 74AHCT595 shift registers with output latches for deserializing motors control data that comes directly from the FPGA. The shift registers demonstrate a driving method requiring less FPGA IOs than it would be required in a case of direct motors driving. The direct driving of 4 stepper motors requires 16 FPGA IO pins. A driving by two shift registers requires only 4 FPGA IO pins: clock, latch, and 2 data pins. The logiSTEP Stepper Motors Controller IP core supports both driving methods.

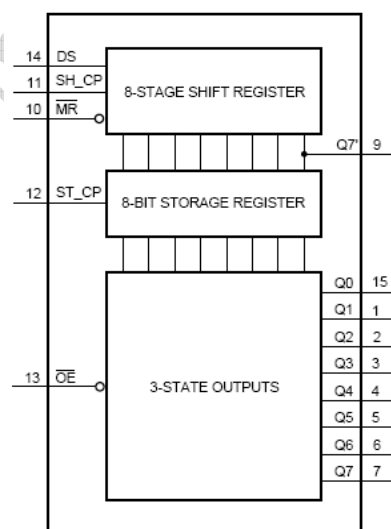


Figure 9: 74AHCT595 Shift Register with Output Latches

## 4.5 Switec Stepper Motors

The logiHAC features miniature stepper motors M-S X25 series manufactured by company Microcomponents SA (a company of the SWATCH group). This motor series was developed primarily as an indicator drive for dashboard instrumentation and other indicator equipment. The main features are listed below:

- 1/3° resolution per step
- Low current consumption
- Small dimensions:  $\phi$  30 x 9 mm
- Can be directly driven by a MCU
- Large temperature range: -40° to 105°C
- High speed: > 600 °/s
- Qualified for automotive applications



**Figure 10: Switec Stepper Motor**

MANUFACTURER:

**Microcomponents SA**

Oelirain 5

CH-2540 Grenchen

Suisse

[www.microcomponents.ch](http://www.microcomponents.ch)

## 4.6 logiHAC Pointers

logiHAC gauges use A.MAIER Präzision GmbH pointers:

- Pointer type 31357 (44 mm)
- Pointer type 31021 (34 mm)

MANUFACTURER:

**A.MAIER Präzision GmbH**

Gewerbellestr. 1-3

D-78112 St. Georgen, Germany

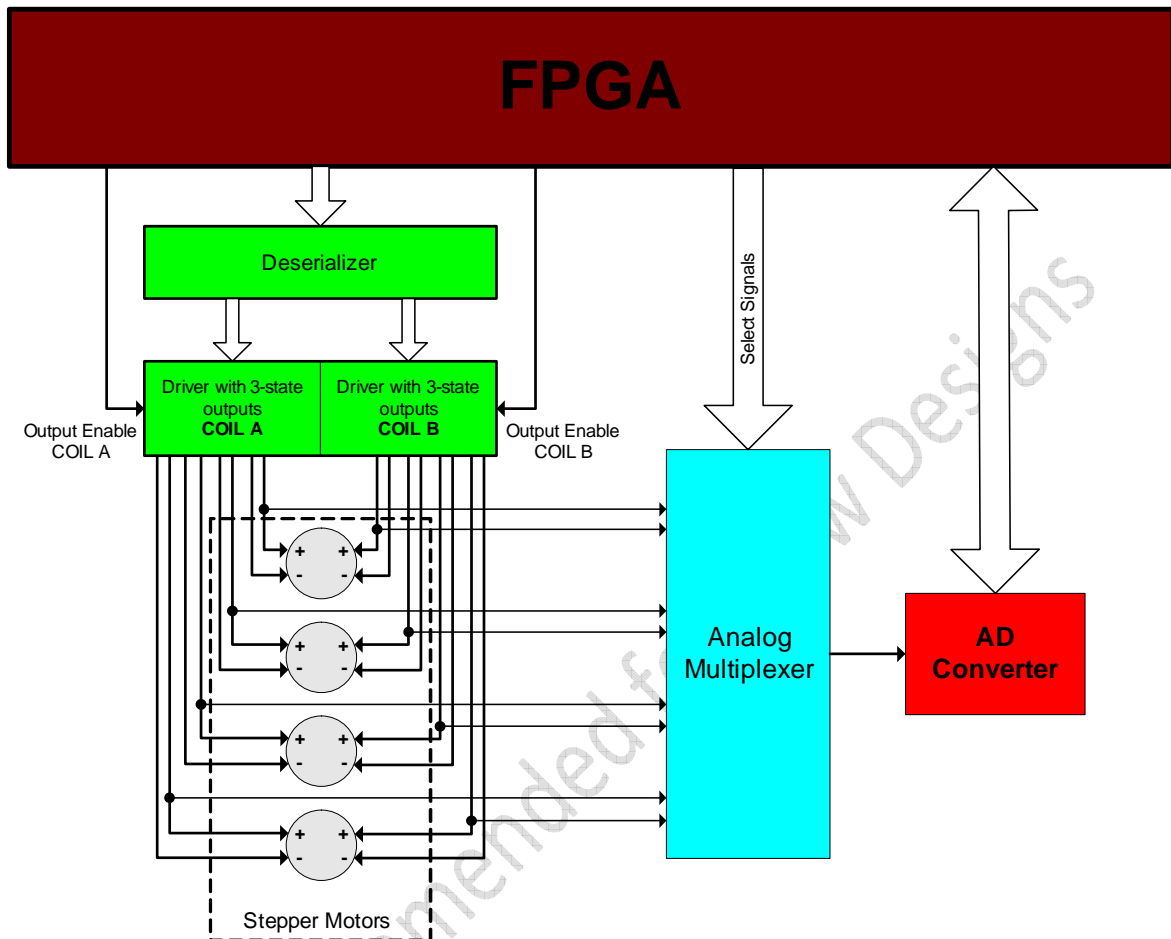
[www.a-maier.de](http://www.a-maier.de)

## 4.7 Zero Position Detection circuitry

Because of analog nature of measured EMF signals during the Zero Detection procedure, the FPGA requires an additional external hardware. The Zero Position Detection is based on sensorless stall detection.

Additional external hardware for Zero Position Detection is tailored to provide low-cost stall detection for multiple motors. The Zero Positioning is done by stall detection on single stepper motor at time.

Basic block diagram is shown on Figure 11:



**Figure 11: Hardware for the Zero Position Detection**

FPGA drives single stepper motor via line driver, and alternately enables/disables coil A and coil B. EMF voltage induced on non-driven coil is multiplexed by an analog multiplexer and measured by SAR (Successive Approximation Register) AD Converter.

## 5 logiHAC+HUD FPGA Design

The logiHAC+HUD Development Kit provides a work frame for development of GUI based embedded applications. Due to this reason, the Kit offers strong graphics capabilities. The graphics capabilities are supported by an FPGA reference design made as a blend of Xilinx IP cores available within the Xilinx EDK's IP Catalog and Xylon logicBRICKS™ IP cores. Additionally the FPGA design features the logiSTEP Stepper Motors Controller that is necessary for analogue gauges control.

The reference design is based on the Xilinx MicroBlaze soft-CPU acting as a microcontroller (MCU) controlling all system functions. Typical embedded MCUs (including the MicroBlaze) do not have enough computing performance to control the system and adequately render GUI graphics. The MCU typically require an aid from a dedicated hardware graphics controller that offloads the graphics rendering burden.

Selected logicBRICKS™ IP cores for the reference design support different graphics functions. The Xilinx Platform Studio (XPS) and the EDK tools fully support the logicBRICKS™ IP cores and users can access them in a same manner as Xilinx IP cores from the EDK IP catalog.

The FPGA reference design implements fully featured 2.5D graphics controller integrating different graphics features, including bitmaps operations, alpha blending, overlays, rotations, scaling, LCD control, video input capture, etc.

Any graphics controller has an LCD controller driving LCD displays with various resolutions, timing requirements, and color depths. The logiCVC-ML Compact Video Controller carries out this function within the FPGA. This logicBRICKS™ IP core includes an LVDS serializer and directly interfaces the color LCD touch display with no need for any additional on-board electronics.

Efficient graphics controllers implement different sorts of graphics accelerators. The logiBITBLT Bit Block Transfer IP core is a 2D graphics accelerator supporting complex bitmap operations like copying, moving, alpha blending, and Porter & Duff compositing operations between different graphics objects. The 2D graphics acceleration is further expanded by the logiBMP Bitmap 2.5D graphics accelerator logicBRICKS™ IP core. The logiBMP supports very complex bitmap operations like texture renderings, picture filtering, up and down scaling, and bitmap rotating. The logiBITBLT and the logiBMP IP cores support smooth transitions and animations.

The image transformation necessary for the HUD demo LCD is done by logicBRICKS™ logiVIEW\_Lite image processing IP core

Video input feature of the reference FPGA is supported by the logicBRICKS™ logiWIN Versatile Video Input IP core. This IP core performs capture of the ITU 656 or LVDS digital video input, color space conversion, cropping, scaling and de-interlacing. The captured video can be blended with logiCVC-ML graphic layers and displayed on the LCD.

The memory subsystem is an essential part of any graphics based system. It must ensure the design has a fast memory bandwidth and enough storage space for GUI elements and application code. The logiHAC+HUD include the 16-bit DDR SDRAM memory interfaced by the FPGA by a mean of the Xilinx MPMC (Multi-Port Memory Controller) and logicBRICKS™ logiMEM\_arb arbiter and bridge to Spartan6 MCBs. Together, they represent the cluster SDRAM memory controller. This multi-ported SDRAM memory controller enables various IP cores to use common memory devices. Each IP uses granted memory bandwidth share setup by the logiMEM\_arb IP configuration.

Figure 12 presents the reference design block diagram.

## 5.1 FPGA Block Diagram

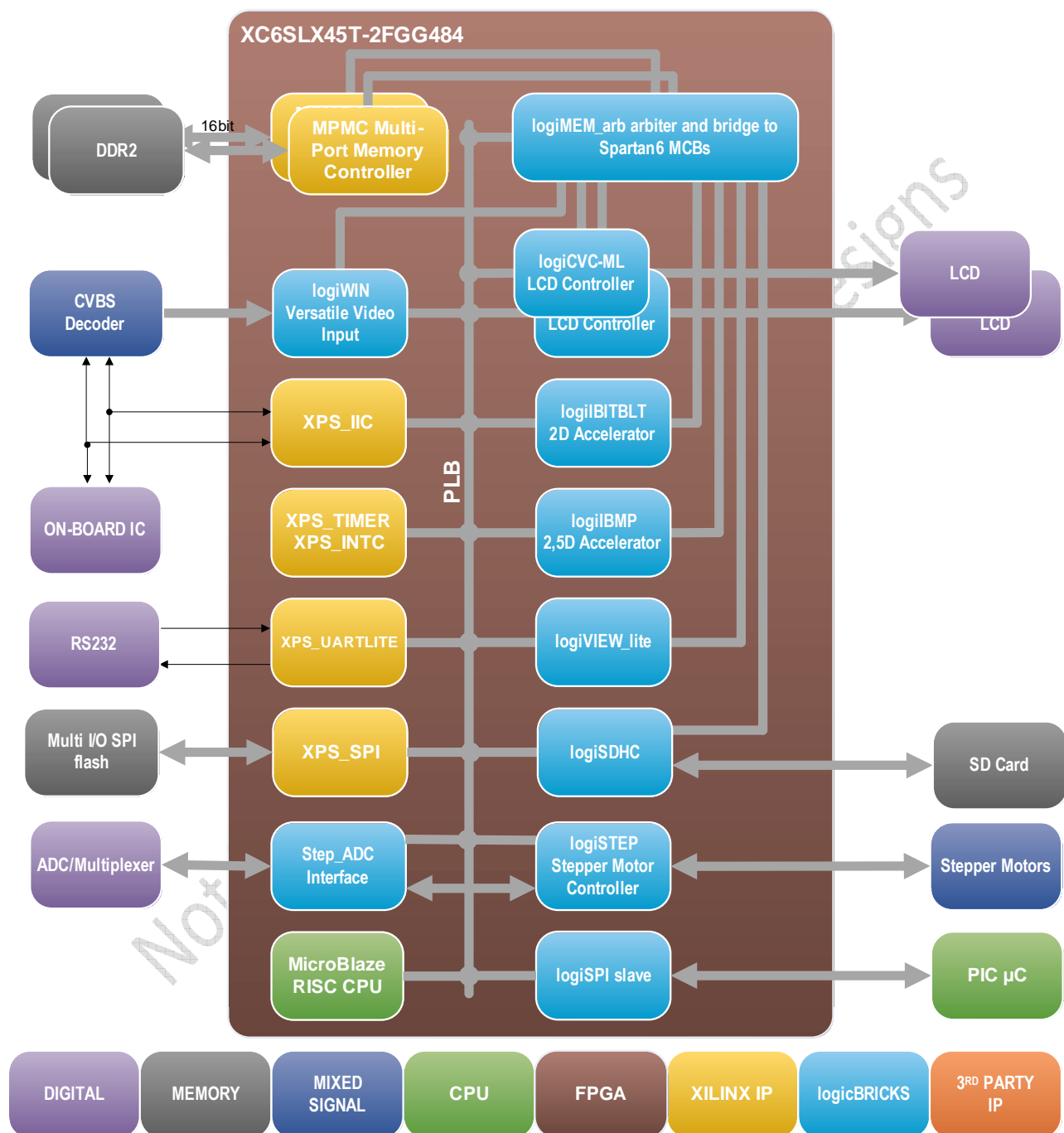


Figure 12: logiHAC+HUD Reference FPGA Block Diagram



## 6 ADC\_STEP IP Core – Interface to an External ADC

### 6.1 General Description

Modern cluster systems featuring stepper motors often use Zero Position Detection (ZPD) which is occasionally (i.e. at the ignition time) executed to determine or check out starting position of the motor's shaft. Starting position is the most left or the most right position of a gauge's scale.

The ZPD is a more sophisticated method of setting up the motor's shaft zero position than the Return to Zero (RTZ) method.

The RTZ is a simple shaft moving for a pre-programmed number of full-steps (One Phase-On) in one direction. The number of pre-programmed full-steps must be big enough to cover a whole gauge scale's sweep and to push the motor's shaft towards an internal stopper, or the load (a needle) mounted on the shaft towards an external stopper.

The ZPD supported by the Xylon logiSTEP Stepper Motors Controller and used in the logiHAC system, is based on measurements of the induced EMF voltage in the non-driven coil while motor moves in the One Phase-On full-step stepping mode.

The induced EMF is measured by an external Analogue-To-Digital converter (ADS7888) that samples amplified EMF voltage generated at the selected motor's coil. External analogue electronics is controlled by the logiSTEP IP core, and by the ADC\_STEP IP core developed to support the interface between the logiSTEP and the ADS 7888 ADC.

Some other systems requiring the ZPD may use other analogue electronics that can be similarly interfaced to the logiSTEP. That electronics can be also an integrated part of a microcontroller interfacing the FPGA with an implemented logiSTEP Stepper Motors Controller IP core.

The ADC\_STEP features:

- Small set of registers for IP programming
- Features an interface (serial) towards the ADS7888 ADC
- Collects and processes samples gathered from the ADS7888 ADC
- Setup ZPD flags connected to the logiSTEP
- Synchronizes logiSTEP outputs for motor's control with 3-state control signals used during the ZPD
- Executes ZPD with 1 motor at the time
- Calibration

The measurement must be executed in the logiSTEP Bypass mode that enables the full-stepping. Currently the implemented measurement method supports measurement on one motor at the time.

## 8 User's Interface Description

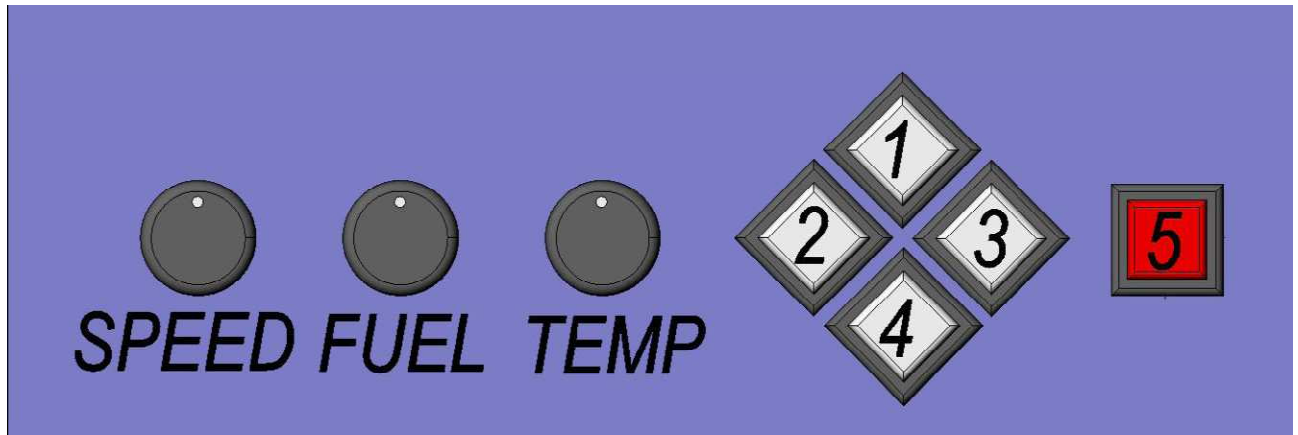


Figure 13: Demo's MMI Commands (sensors)

logiHAC currently supports three modes of operation:

- **Automatic mode** simulating driving. Inputs from the MMI interface are ignored. The only valid input is a key switch combination to the Manual operation mode
- **Manual mode** enabling controlled switching of all cluster screens excluding the intro (Welcome) screen. Gauge pointers movements are controlled by analogue sensors. Some push-buttons can control some selections within a screen.
- **"Needle movements show" mode** of operation demonstrating fast needles movements. In this mode the logiSTEP changes various control parameters controlling needle's speed and movement's smoothness.

Potentiometers are connected to the PIC MCU as analogue inputs, and the PIC's ADC measures input voltages. The measured values are being sent through the SPI bus towards the FPGA featuring logiSTEP stepper motors controller. The logiSTEP positions analogue gauges accordingly to commands issued by a user.

Demo's push-buttons operate as presented by the Table 1. The push-buttons are also monitored by the PIC that actually transfers their states to the MicroBlaze. Different button combinations switch demo's modes of operation.

While in an automatic mode of operation, sensor inputs are ignored. The GUI and the analogue gauges are controlled by the MicroBlaze only.

**Table 1: Push-Buttons Combinations**

Main display	
Pushed Button(s)	Action's Description
1	Moves backward to a previous cluster's screen
2	Move selection tab left within a selected cluster's screen
3	Move selection tab right within a selected cluster's screen
4	Moves forward to a next cluster's screen
5	Selection button in manual mode (or selection between "Zero Position Detection" or "Return to Zero" described in chapter <b>Error! Reference source not found.</b> )
2 & 3 & 5	Holds the FPGA in a reset condition (not programmed) while pushed.
1 & 5	Switch between manual and automatic demo's modes of operation. Switching signalized by buzzer.
2 & 5	Initiates needles parking routine which drives all needles to their physical zero position and turns off display. Needles parking can be done prior to system shutdown to have needles at their zero positions on the next system start to avoid long lasting zero positioning.
4 & 5	Activates/De-Activates needle demo presenting very fast needle movements in manual mode. De-Activation switches back to the original demo state; either automatic or manual demo mode. Mode's activation activates a buzzer too.
3 & 5	Buttons combination for an activation of the LCD display dimming control. The buttons must be simultaneously pushed for 2 sec. Successful activation is signalized by the buzzer. Afterwards, the display's dimming level can be controlled by the TEMP potentiometer. Setup dimming level is saved by 2 sec push on the same buttons combination.
HUD display	
Pushed Button(s)	Action's Description
1 & 4	Enters/Exits HUD display setup mode. The buttons must be simultaneously pushed for 2 seconds while in demo manual mode. Successful activation is signalized by the buzzer. HUD display setup mode is turned off by 2 sec push on the same buttons combination.
5	(When in HUD setup mode). Pushing this key toggles HUD screen correction on and off.
2	(When in HUD setup mode). Pushing this key circularly switches to lower HUD display position.
3	(When in HUD setup mode). Pushing this key circularly switches to higher HUD display position.
TEMP Potentiometer	(When in HUD setup mode). Potentiometer rotation increases or decreases HUD display backlight intensity (brightness).

## 9 Demo Application

This chapter gives a brief description of the application HMI which consists of several graphic screens with different graphic gauges, indicators and user input control (GUI) as well as four mechanical needle gauges.

### 9.1 Welcome Screen

The Welcome screen appears in less than 1 second after a start up. Mechanical pointers are moved to the zero positions.

This screen is not available in the Manual operation mode.



**Figure 14: Start-Up (Welcome Screen)**

*Note: Different logiHAC systems might have pointers positioned in slightly different positions. All demos are hand-made and an exact and repeatable pointers positioning at the assembly time is not possible.*

### 9.2 Gauges Screen

This screen enables selection between 3 different gauges: power meter, econometer, and a navigation gauge.

### 9.2.1 PowerMeter Gauge

The PowerMeter gauge changes its positioning in a correlation to a current speed and rpm. In the Manual mode, the push-buttons 2 and 3 change gauge. Pushbuttons 1 and 4 change screen.



Figure 15: PowerMeter Gauge Screen

### 9.2.2 EconoMeter Gauge

The EconoMeter gauge changes its positioning in a correlation to a current speed and rpm. Push-buttons 2 and 3 change gauge in the Manual mode. Push-buttons 1 and 4 change screen in the Manual mode.



Figure 16: EconoMeter Gauge Screen

### 9.2.3 Navigation Gauge

The Navigation gauge graphically shows driving direction instructions.

Push-buttons 2 and 3 change gauge, and pushbuttons 1 and 4 change screen in the Manual mode.



Figure 17: Navigation Gauge Screen

### 9.3 Rear-View Camera Screen

This screen simulates rear-view DAS system. External CBS camera must be connected to the logiHAC.

A number of different icons are drawn (overlayed) in the video window. In the manual mode, the icons are exchanged by push-buttons 2 and 3. Push-buttons 1 and 4 change screen.



Figure 18: Camera Screen



## 9.4 Parking - Pedestrian Sensors Screen

The Pedestrian Sensors signalize a distance from pedestrians or mech obstructions around a car. Push-buttons 1 and 4 change screen. Push-buttons 2 and 3 activates different sensors in the Manual mode.



Figure 19: Pedestrian Sensors Screen

## 9.5 Trip Computer Screens

Push-buttons 2 and 3 change between SPEED and TIME trip computer screens (push-button 5 confirms selection). Push-buttons 1 and 4 change screen.



Figure 20: Trip Computer Screen

## 9.6 HUD Screen

This screen is displayed on the HUD display, corrected, and projected on the HUD windshield. The screen continually shows speed and navigation data, sourced from the main logiHAC screens. Screen setup mode allows adjustment of the screen reflection position on the windshield, image correction control and display brightness control (Chapter 8).



Figure 21: HUD screen projected on the windshield

## 9.7 Mechanical Gauges

There are 4 mechanical gauges driven by Switec stepper motors. Their behavior can be manually controlled by Demo's potentiometers, or automatically in the Demo's automatic mode.

### 9.7.1 Mechanical Gauges Control

Not Recommended for New Designs

**Figure 22: Mechanical Gauges Control**