APPLICATION NOTE

REF8116_CCD
VGA USB CAMERA
WITH MICROPHONE

AN00065

Philips
Semiconductors

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Abstract

This document is related to the CCD cameras built around the SAA8116.

Those camera use VGA CCD sensors (Sony ICX098 or Sharp LZ24BP family), the TDA8787A as front-end IC and have a microphone functionality.

This document includes schematics, layouts and part lists, and a few comments on possible adaptations.

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VGA CCD sensors
USB
microphone

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1 Introduction

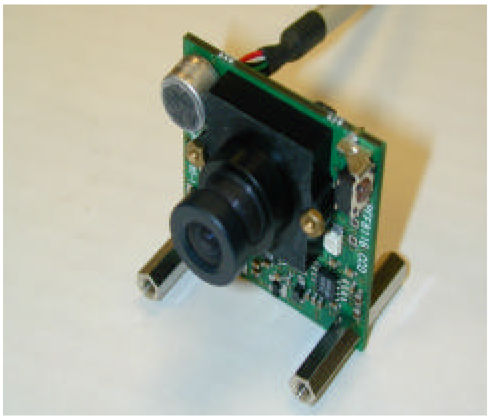
1.1 SAA8116 overview

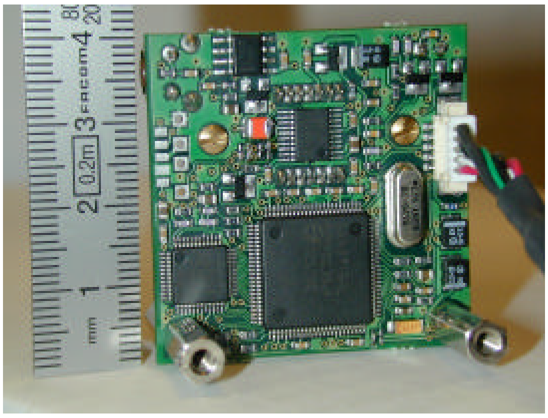
The SAA8116 is a PC-Camera signal processor, including a microcontroller and a USB interface, performing a very low cost solution for a USB PC camera.

It integrates a video data processing, including statistical measurement facilities for auto-control loops (auto exposure, auto white balance and auto optical black adjustment), a pulse pattern generator (PPG) for the CCD control, a video formatter and compressor, the USB interface and the microcontroller.

This IC is compliant with VGA CCD sensors as well as with some VGA CMOS sensors (RGB Bayer).
In CCD applications, it can be used in combination with the TDA8787A that performs the CCD data digital conversion.

1.2 Application overview



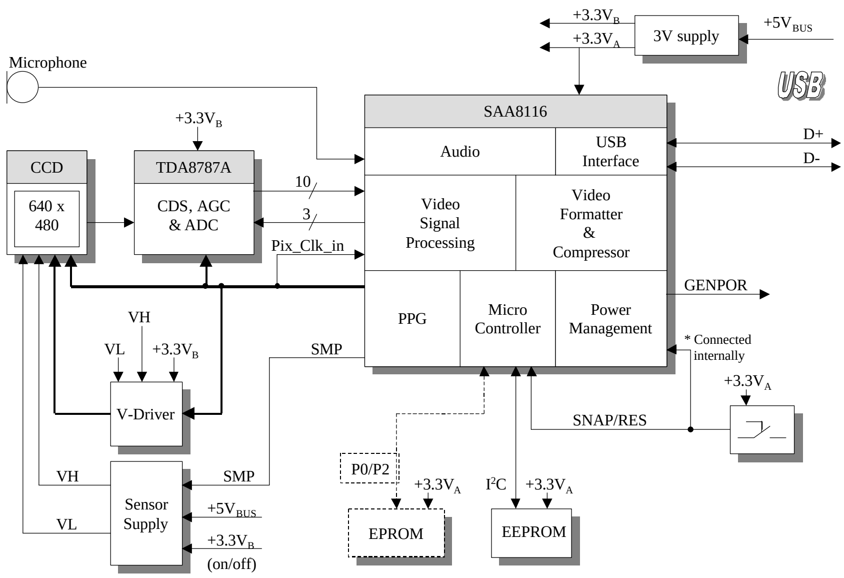


The goal of this reference design is to demonstrate the functionality and the performances of the SAA8116 in a CCD application.

The chosen CCD is the Sony ICX098 VGA, or the Sharp LZ24BP. The application has been validated with the Sony sensor.

It provides a complete video and audio processing and encoding into the USB format.
The video processing includes auto-exposure and auto-white balance facilities. This processing is done by the embedded software driving the SAA8116.

An application diagram is given by the figure below.



1.3 Reference documents

"**SAA8116,** Digital PC-Camera signal processor including microcontroller and USB interface", preliminary specification, 23 June 2000.

1.4 Abbreviations and acronyms

Front-end is meant for CCD + TDA8787A + vertical driver.

ADC	Analog to Digital Converter
CCD	Charge Coupled Device
CDS	Correlated Double Sampling
CMOS	Complementary Metal-Oxide-Silicon : IC technology and, by extension, type of imaging sensor
EEPROM	Electrically Erasable Programmable Read Only Memory
EPROM	Electrically Programmable Read Only Memory
ESD	Electrostatic Discharge
I^2C	Inter Integrated Circuit bus (2-wires serial bus)
PC	Personal Computer
PPG	Pulse Pattern Generator

RGB-Bayer	Type of color filter, based on Red, Green and Blue patterns
SMD	Surface Mounted Device
USB	Universal Serial Bus
VGA	Video Graphic Adapter : by extension, image format (640x480 pixels)

2 REF8116_CCD, v2.0

2.1 Application description

The application described in this chapter exactly corresponds to the previous diagram.
It is composed of the following main components :

- CCD : ICX098 from Sony or LZ24BP from Sharp
- vertical driver : uPD16510 from NEC
- analog front-end : TDA8787A (Philips)
- SAA8116
- power supply units
- microphone
- EEPROM to store the camera settings : Philips PCF8594C or equivalent (ST M24C04)
- external EPROM (Atmel AT27LV520)

2.2 Blocks descriptions

2.2.1 Supplies

The power supply is totally provided by the USB bus. It is a +5V supply.
All the digital part of the camera works at 3.3V. Only the front-end part (CCD and vertical driver) needs additional supplies which values may depend on the sensor : VL (-5V to –9V) and VH (+14V or +15V).

The 3.3V is delivered by a regulator.
In order to reduce the camera power consumption in suspend mode, the 3.3V supply to the front-end part may be switched off by the microcontroller, through the FPn pin (Full power). However, the regulator used as example on this reference design (MC33275D-3.3 from Motorola) is not really suitable due to its rather high quiescent current (125 uA), which is one of the factor entering in the suspend mode current consumption. A circuit having a lower quiescent current (TPS76633 from Texas Instrument for instance) would be prefered.

Because the analog part of the TDA8787A may flow a rather important current at start-up, a polarized capacitance is useful on that supply. It is then also useful to separate the analog and digital supplies of this IC (VCCa and VCCd).

The CCD is powered by VL and VH supplies. The vertical driver also has to deliver signal with those amplitudes. Therefore it is also supplied by those voltages.

In order to generate such values, two Switch Mode Power Supply stages are used, driven by an adjustable SMP square pulse generated by the SAA8116.

2.2.2 Front-end

The front-end part of the camera is made of the CCD, the vertical driver and the TDA8787A. Vertical driver and TDA8787A synchronization pulses are delivered by the PPG part of the SAA8116.
The schematic is built according to those components data sheets.

In addition, the schematic is compatible for Sony ICX098 and Sharp LZ24BP sensors. Therefore, a few vertical pulses have to be configurable. Part of this flexibility is offered by the SAA8116 on pin FV3 that can be set either equal to FV2 (for Sony CCD) or to FV4 (for Sharp CCD). Also, some configuration capabilities are foreseen on the board :

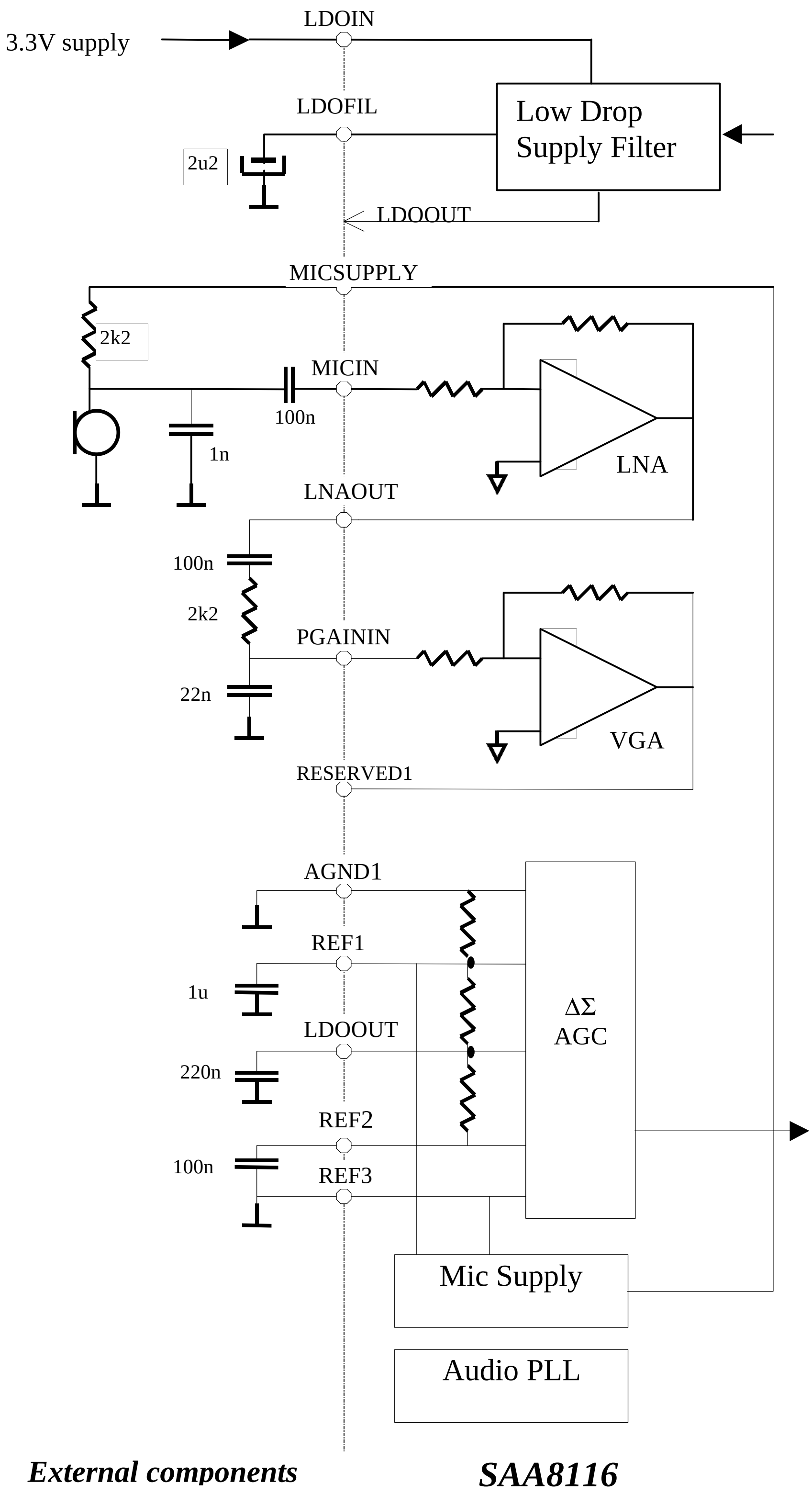
	Sony ICX098		Sharp LZ24BP	
	Configuration	Link uPD16510 to SAA8116	Configuration	Link uPD16510 to SAA8116
TC8	Open	BI2 = FV1	Closed	BI2 = FV2
TC9	Closed		Open	
TC10	Closed	BI1 = FV4	Open	BI1 = FV1
TC11	Open		Closed	

2.2.3 Digital video processing

The digital video processing is made in the SAA8116, controlled by the embedded microcontroller. Very few external components are required.
The microcontroller code may be embedded in an external EPROM. In that case, an Atmel AT27LV520 is used, which has the particularity of having internal latches for code and data, avoiding any external circuitry.

2.2.4 Audio

The audio function is implemented according the SAA8116 designers recommendations.


3.3V supply
LDOIN
LDOFIL
Low Drop
Supply Filter
2u2
LDOOUT
MICSUPPLY
2k2
MICIN
100n
1n
LNA
LNAOUT
100n
2k2
PGAININ
22n
VGA
RESERVED1
AGND1
REF1
1u
LDOOUT
220n
ΔΣ
AGC
REF2
100n
REF3
Mic Supply
Audio PLL
External components
SAA8116

The microphone on the reference design is a multidirectional microphone, with the following characteristics :
Frequency : 20 Hz to 12 kHz
NSR > 40dB
Output impedance : 150Ω to 5 kΩ
Sensitivity : 63 dB

2.2.5 External connections

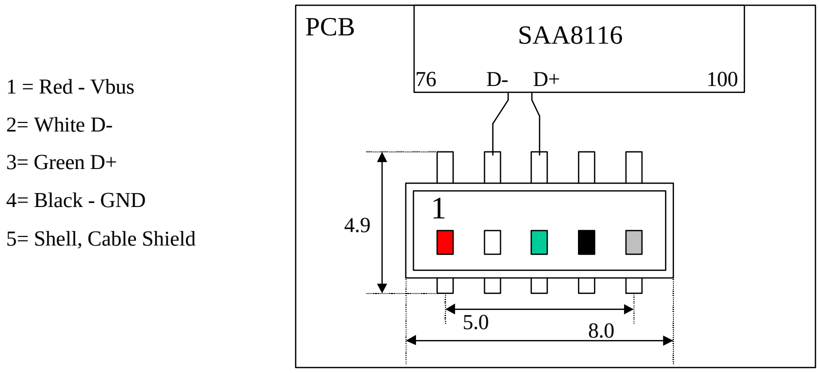
Only two external connections are available on the board :
- the USB bus
- an I^2C link for EEPROM loading and factory alignment purpose.

2.2.5.1 USB bus

The USB bus provides :
- audio, video and commands communication between the camera and the host PC,
- the camera +5V supply.

The on-board connector is the following :

USB Connector - Straight SMD 1.25mm pitch
Top View - dimension in mm



To be connected to USB cable with female adapter on one side and USB A plug (rectangular one) on the other side.

This link is USB compliant : the software and power management compliance is assured by the SAA8116 hardware and by the software. Voltage levels and ESD protection are provided on the board.

2.2.5.2 I²C link

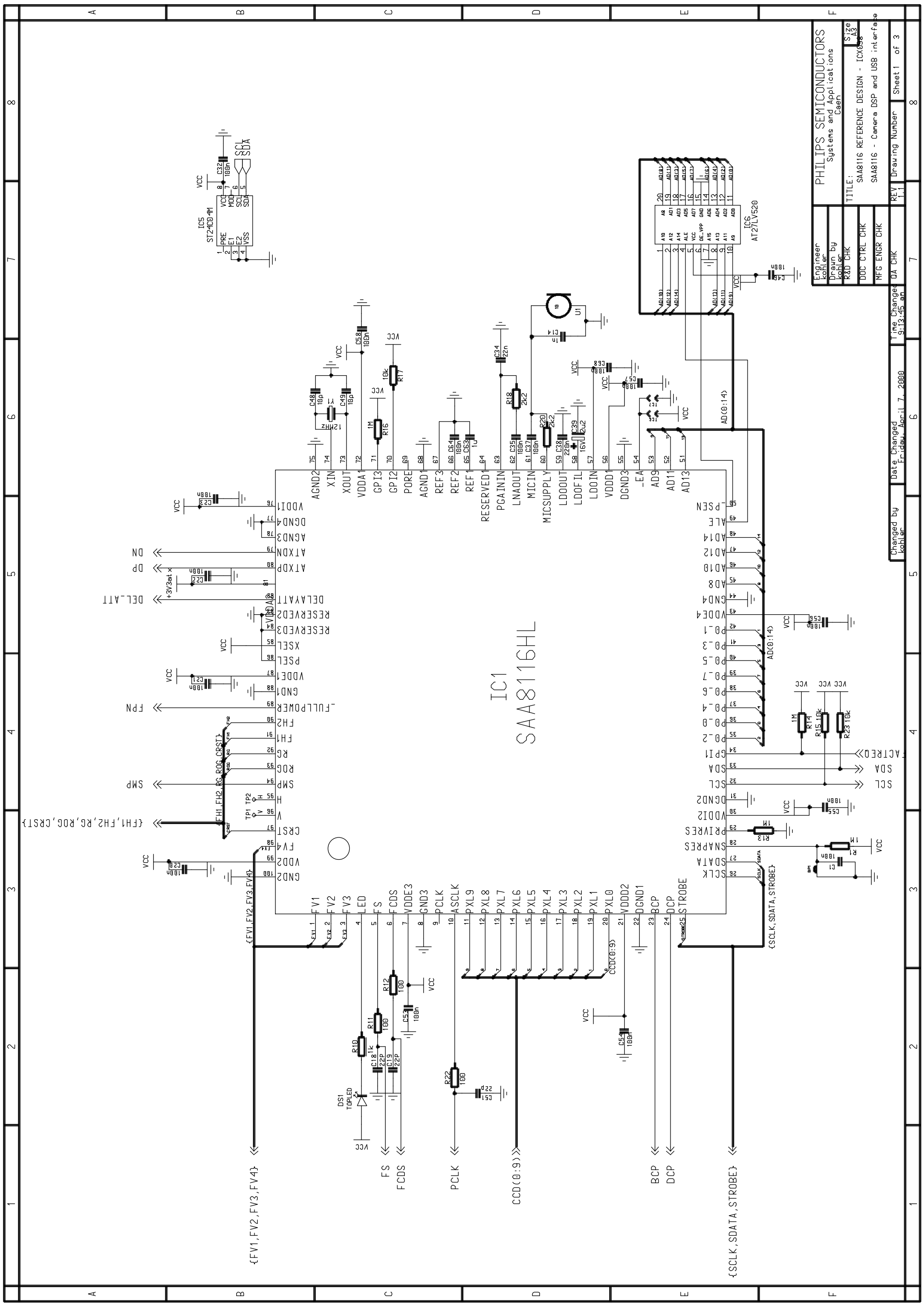
The I^2C bus is meant for test and alignment purposes only. It is not used in normal application: for demonstration purpose it is possible to modify all camera parameters through USB.
Therefore it has been chosen not to have any connector soldered on the SMD areas.
The pin FACTREQn may be used during alignment procedure to disable the I^2C communication with the SAA8116 (when direct load of the EEPROM for instance).
The pinning is the following :

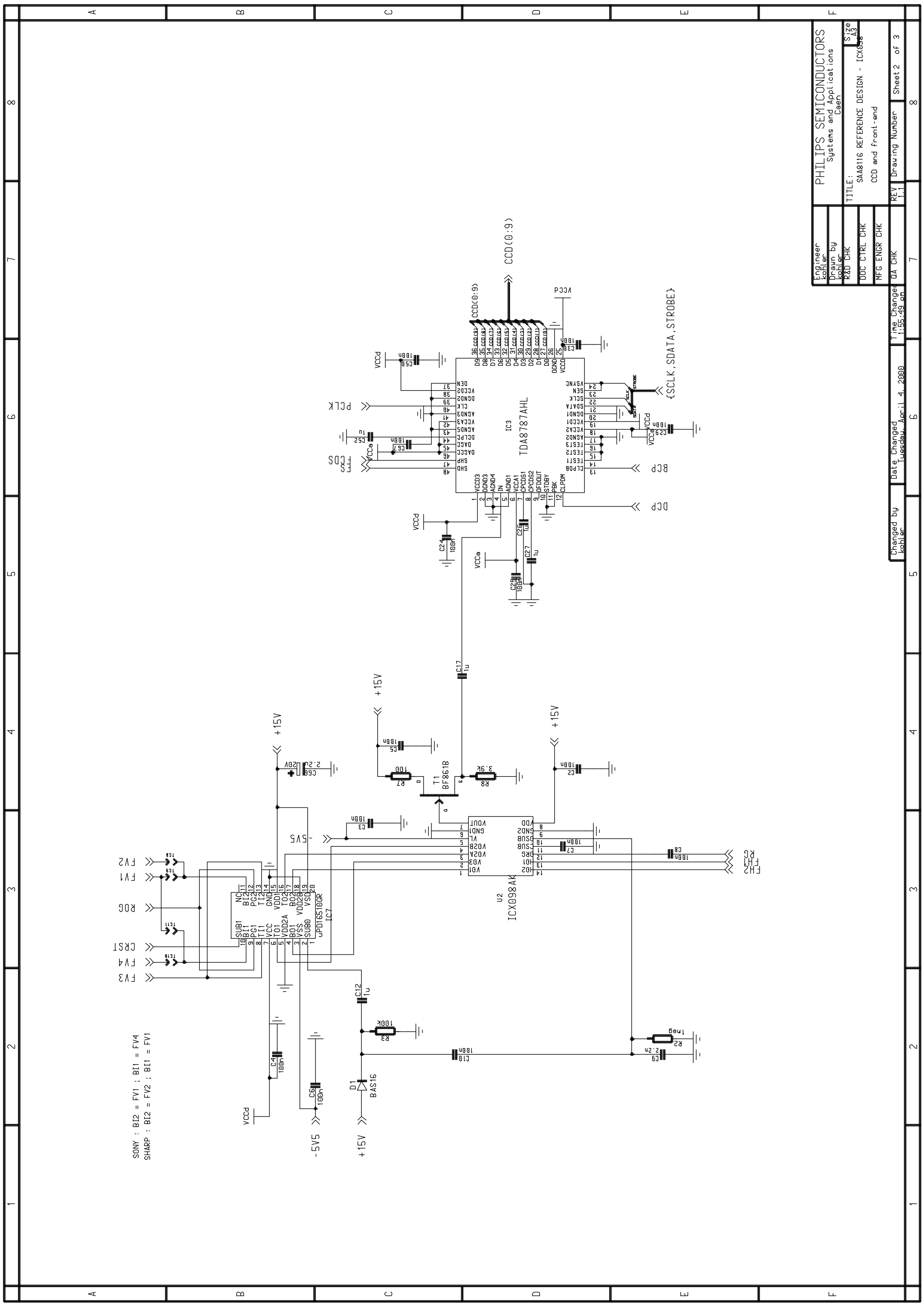
1	CLK
2	GND
3	+5V
4	SDA
5	FACTREQn

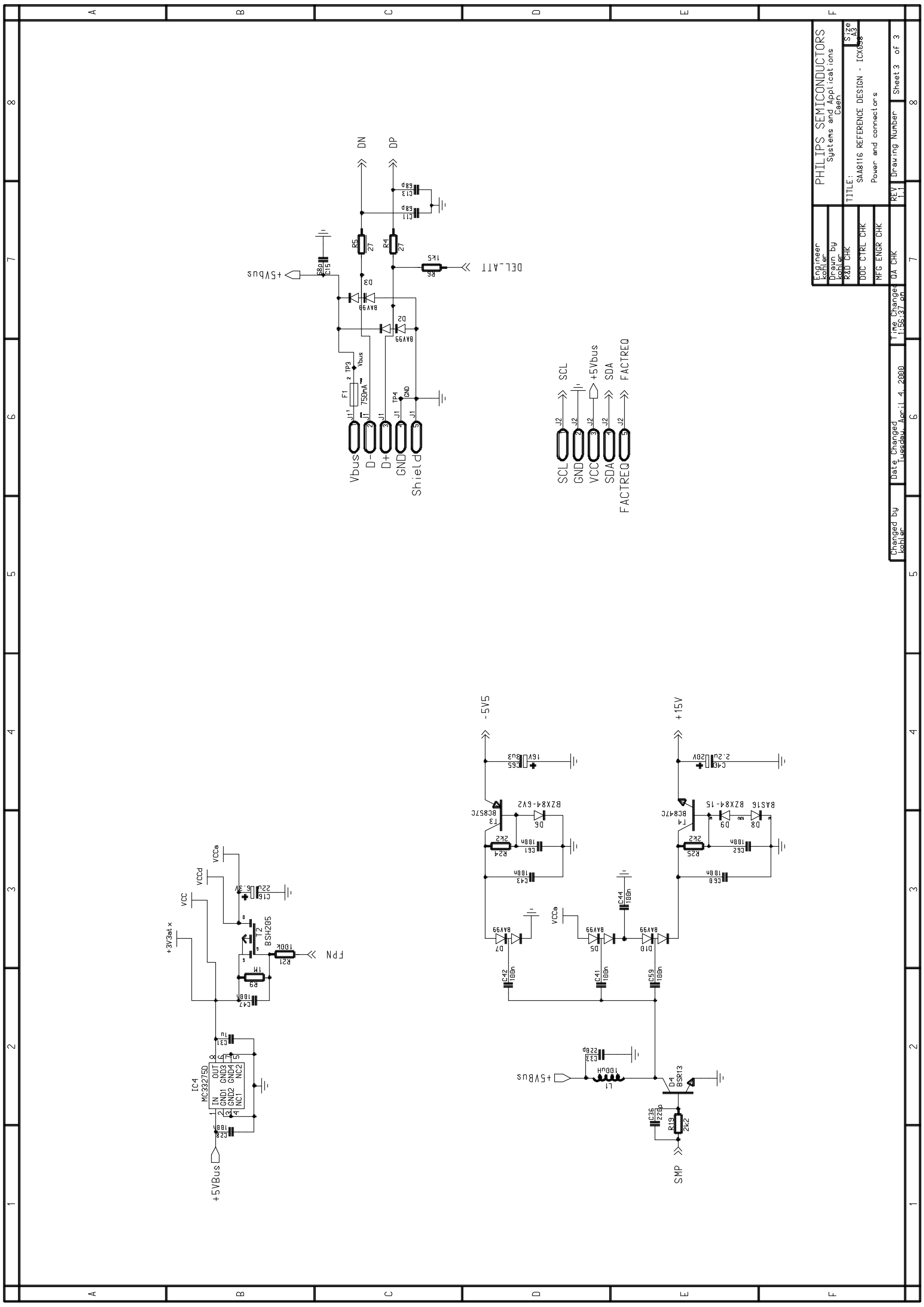
2.2.6 Snapshot

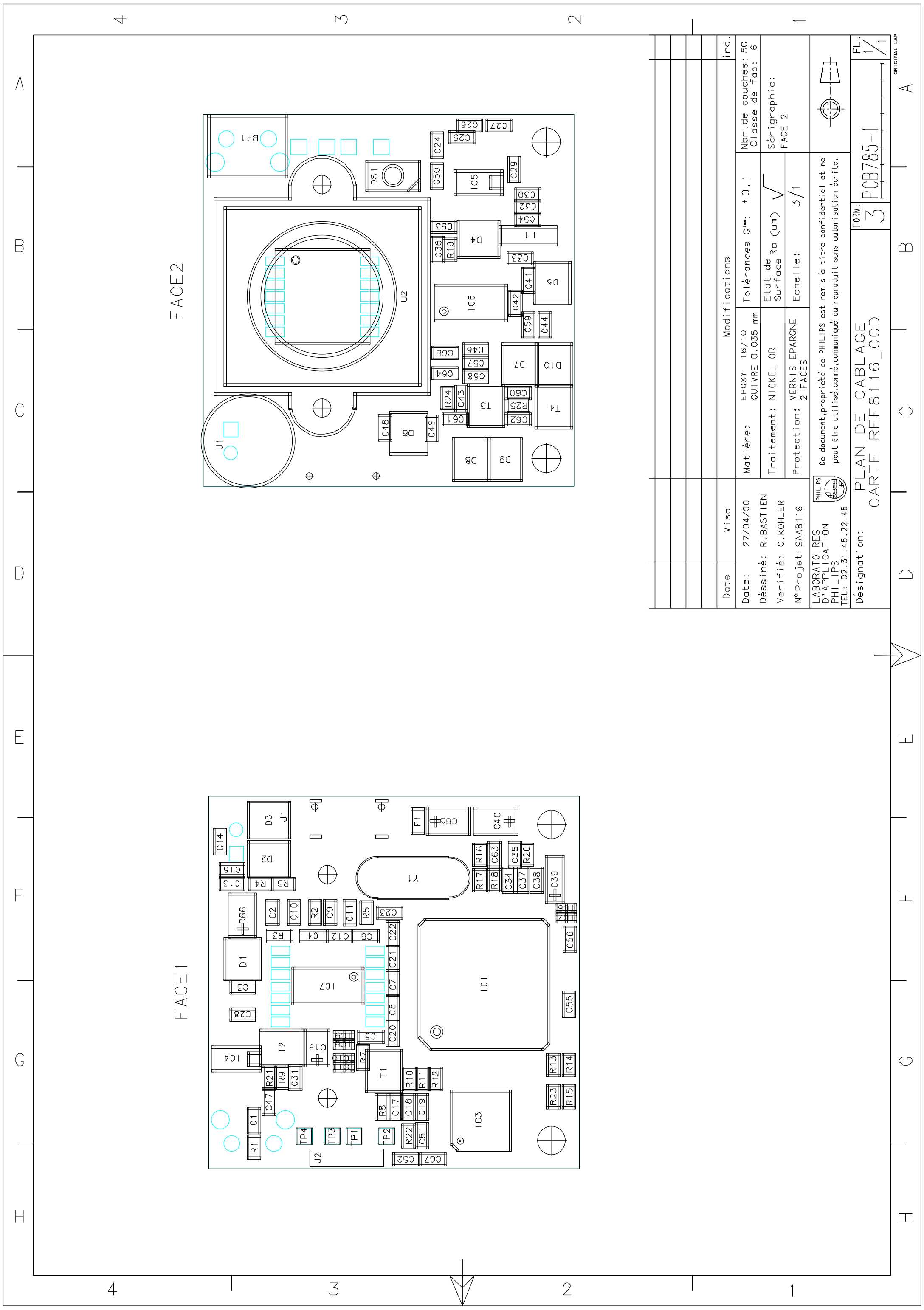
A Snapshot pushbutton is available on the camera, which allow to take a photograph of the scene.

2.3 Schematics, layouts and mechanics


IC1
SAA8116HL
PHILIPS SEMICONDUCTORS
Systems and Applications
Caen







PCB 785-2 : REF8116_CCD
PART LIST

REFERENCE	DESCRIPTION	GEOMETRY
---------	-----------	--------
BP1	MICROSWITCH	bp959-704
C1	C0603, 100n	C0603
C2	C0603, 100n	C0603
C3	C0603, 100n	C0603
C4	C0603, 100n	C0603
C5	C0603, 100n	C0603
C6	C0603, 100n	C0603
C7	C0603, 100n	C0603
C8	C0603, 100n	C0603
C9	C0603, 2.2n	C0603
C10	C0603, 100n	C0603
C11	C0603, 68p	C0603
C12	C0603, 1u	C0603
C13	C0603, 68p	C0603
C14	C0603, 1n	C0603
C15	C0603, 68p	C0603
C16	C595D_A, 10u	595D_A
C17	C0603, 1u	C0603
C18	C0603, 22P	C0603
C19	C0603, 22P	C0603
C20	C0603, 100n	C0603
C21	C0603, 100n	C0603
C22	C0603, 100n	C0603
C23	C0603, 100n	C0603
C24	C0603, 100n	C0603
C25	C0603, 100n	C0603
C26	C0603, 1u	C0603
C27	C0603, 1u	C0603
C28	C0603, 100n	C0603
C29	C0603, 100n	C0603
C30	C0603, 100n	C0603
C31	C0603, 1u	C0603
C32	C0603, 100n	C0603
C33	C0603, 220p	C0603
C34	C0603, 22n	C0603
C35	C0603, 100n	C0603
C36	C0603, 220p	C0603
C37	C0603, 100n	C0603
C38	C0603, 220n	C0603

C39	C293D_A, 2u2	293D_A
C40	C293D_B, 2.2u	293D_B
C41	C0603, 100n	C0603
C42	C0603, 100n	C0603
C43	C0603, 100n	C0603
C44	C0603, 100n	C0603
C46	C0603, 100n	C0603
C47	C0603, 100n	C0603
C48	C0603, 33p	C0603
C49	C0603, 33p	C0603
C50	C0603, 100n	C0603
C51	C0603, 22p	C0603
C52	C0603, 1u	C0603
C53	C0603, 100n	C0603
C54	C0603, 100n	C0603
C55	C0603, 100n	C0603
C56	C0603, 100n	C0603
C57	C0603, 100n	C0603
C58	C0603, 100n	C0603
C59	C0603, 100n	C0603
C60	C0603, 100n	C0603
C61	C0603, 100n	C0603
C62	C0603, 100n	C0603
C63	C0603, 1u	C0603
C64	C0603, 100n	C0603
C65	C293D_B, 3u3	293D_B
C66	C293D_B, 2.2u	293D_B
C67	C0603, 100n	C0603
C68	C0603, 100n	C0603
D1	BAS16	SOT23
D2	BAV99	SOT23
D3	BAV99	SOT23
D4	BSR13	SOT23
D5	BAV99	SOT23
D6	BZX84, BZX84-6V2	SOT23
D7	BAV99	SOT23
D8	BAS16	SOT23
D9	BZX84, BZX84-15	SOT23
D10	BAV99	SOT23
DS1	TOPLED	PLCC2
F1	FUSELENT, 750mA	C0603
IC1	SAA8116HL	SOT407_1
IC3	TDA8787AHL	SOT313_2

IC4	MC33275D	SOT96_1
IC5	ST24C04M	SOT96_1
IC6	AT27LV520	SOT360_1
IC7	uPD16510	SOT360_1
J1	EDGE	con_usb_chp2505-0101
J2	EDGE	CONN1X5MV_HE14
L1	LQH1N, 100uH	LQH1N
R1	RC21, 1M	R0603
R2	RC11, 1meg	R0603
R3	RC11, 100k	R0603
R4	RC21, 27	R0603
R5	RC21, 27	R0603
R6	RC21, 1k5	R0603
R7	RC11, 100	R0603
R8	RC11, 3.9k	R0603
R9	RC21, 1M	R0603
R10	RC21, 3.3k	R0603
R11	RC21, 100	R0603
R12	RC21, 100	R0603
R13	RC21, 1M	R0603
R14	RC21, 1M	R0603
R15	RC21, 10k	R0603
R16	RC21, 1M	R0603
R17	RC21, 10k	R0603
R18	RC21, 2k2	R0603
R19	RC21, 2k2	R0603
R20	RC21, 2k2	R0603
R21	RC21, 100k	R0603
R22	RC21, 100	R0603
R23	RC21, 10k	R0603
R24	RC21, 2k2	R0603
R25	RC21, 2k2	R0603
T1	BF861B	SOT23
T2	BSH205	SOT23
T3	BC857C	SOT23
T4	BC847C	SOT23
TC6	TP	
TC7	TP	
TC8	TP	
TC9	TP	
TC10	TP	
TC11	TP	
TP1	TEST POINT	
TP2	TEST POINT	
TP3	TEST POINT	

TP4	TEST POINT	
U1	MICRO	micro_mic10
U2	ICX098AK	DMPP14_OPT1_LENSHOLDER
Y1	XTAL, 12MHz	RW43V

The lens and its corresponding lens mount have been ordered at Sunex (reference respectively DSL500 and CMT-003). The size of this mechanical part is one of the constraints to reduce the board size.

2.4 Associated software

This camera works with software developed by Philips Semiconductors.
The “embedded software”, located either in the SAA8116 itself or in an external EPROM (AT27LV520), is in charge of driving the camera including power management according to the USB norm, processing the image (auto-exposure, auto-white balance, auto-black level …).
The “host software” includes all necessary PC drivers to control the camera. It is compatible with Windows 98 and Windows 2000. For demonstration purpose, a sample application called DSCAM is provided.

2.5 Validation results

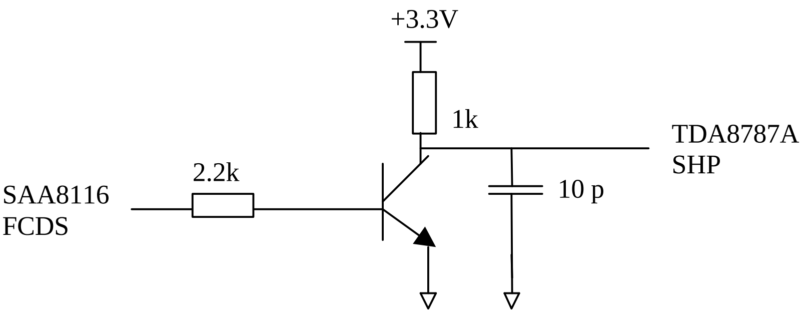
The camera validation has shown two issues for which solutions are known.

- The current consumption in suspend mode is too high : 520 uA instead of max. 500 uA.

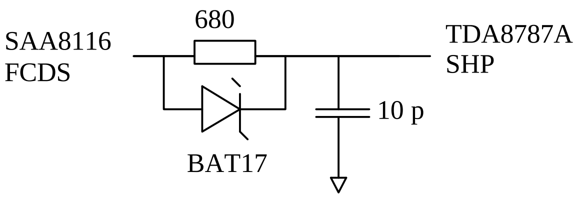
The regulator should be changed to lower the suspend mode consumption : the parameter to be considered is the “quiescent current”, that should be as low as possible (< 50 uA). For instance, the TPS76633 from Texas Instrument could be used. It just need to be verified if the capacitors on the different 3.3V need to be enlarged in order to minimize the ripple.

- Stripes are visible on the picture in low light conditions, at high frame rates (especially 30fps).

These stripes are due to the fact that the SAA8116 PPG is delivering a SHP pulse too small for the TDA8787A (< 9 ns).
A software turnaround has been implemented which consists in limiting the maximum gain at high frame rate, in order not to amplify the noise and the stripes. However, in some light conditions the stripes are still visible.
It could then be useful to implement a hardware compensation, to enlarge the pulse. This solution has been tested but is very difficult to implement on the small reference design and would require a redesign. Hereafter are two possible schematics for this compensation :



OR



On this last schematic, a BAT17 can be used because it has a low forward voltage and a low parasitic capacitance. This solution results in a about 15 ns SHP pulse width.
A standard diode BAS16 could also be chosen as a cheapest solution, although it gives less good results (about 12 ns SHP pulse width).

3 Other schematics and possible modifications

Apart the two problems mentioned above, other modifications or adaptations can be made on the boards.

3.1 Possible simplifications and layout size reduction

Some simple modifications can be made on the schematic in order to simplify it and reduce the board dimension :
- dedicate the board to either the Sony or the Sharp application, removing the corresponding jumpers
- remove resistors on GPI
- remove capacitance on Snapshot (software debouncing is sufficient)

In addition, quite a lot of polarized capacitors are used on that board, according the recommendations of the ICs manufacturers. Some of them could be replaced by non-polarized ones or even removed:
- It is mandatory to have a polarized capacitor only on the VCCa (analog 3.3V of the TDA8787A), with a recommended minimum value of 22u.
- Capacitors C40 and C65 on CCD supplies may even be removed.

- All other could be replaced by 1uF non-polarized capacitors.

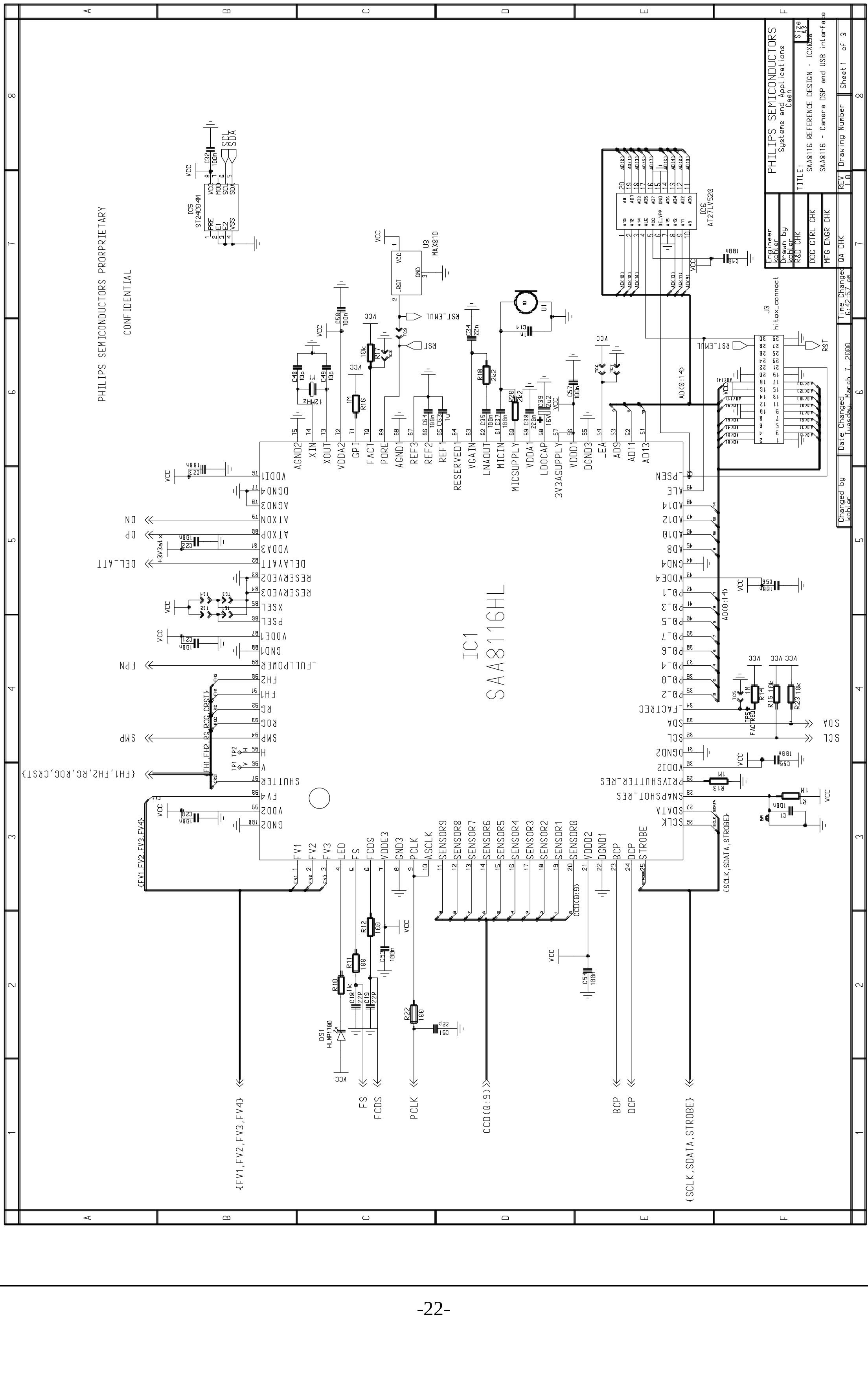
However, the performance of the camera has only been evaluated with all capacitors on board. It would be useful to further study the consequences of removing or changing these capacitors on the noise and global performance of the camera, depending on the layout.

Some components part numbers or geometry have been chosen on the reference design only for their ease of use or because they were easy to find in small quantities (especially in France). For instance :

- the optical mechanical part (lens mount) could be optimized or removed in production (included in the plastic box of the camera)
- the crystal could be in SMD package (this option was not relevant on the reference design)
- a smaller push button and a smaller microphone could be used
- in order to facilitate the manual soldering operation, all resistors and non-polarized capacitance are in 0603 geometry. They could be in smaller dimensions.

3.2 REF8116_ICX098 (v1)

A previous version of the reference design has been issued for the Sony application. The main difference is the use of the Sony vertical driver CXD1267AN. This version gives also good results. The board is not distributed because it has some minor bugs that need additional manual work. The following schematic has been updated to correct those bugs.
This application also contains a connector for software emulation facilities.
The size of this board was also not optimized (5mmx5mm).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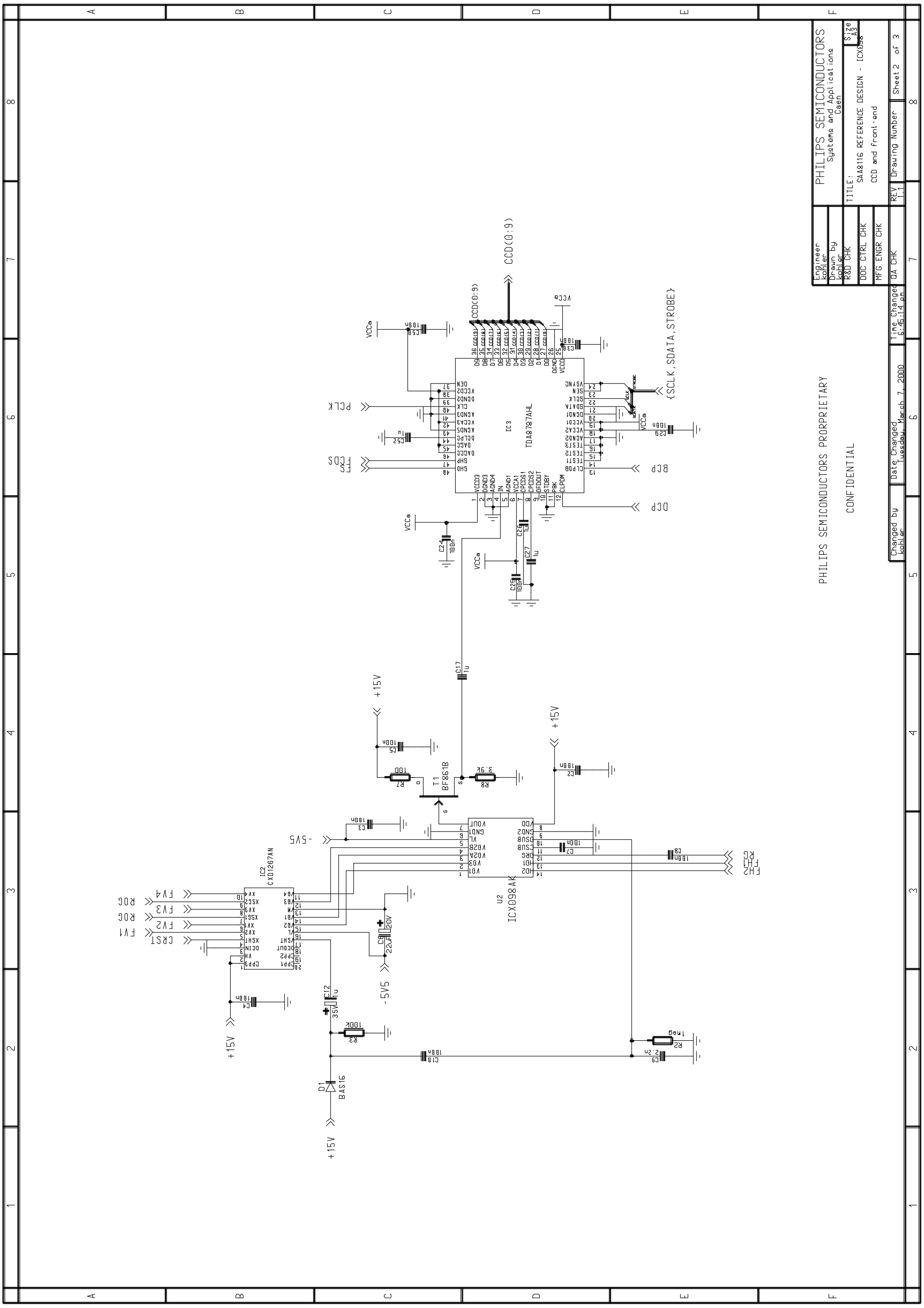
Systems and Applications
Caen
SAA8116 REFERENCE DESIGN - ICX098
SAA8116 - Camera DSP and USB interface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Systems and Applications
Caen
SAA8116 REFERENCE DESIGN - ICX098
CCD and front-end
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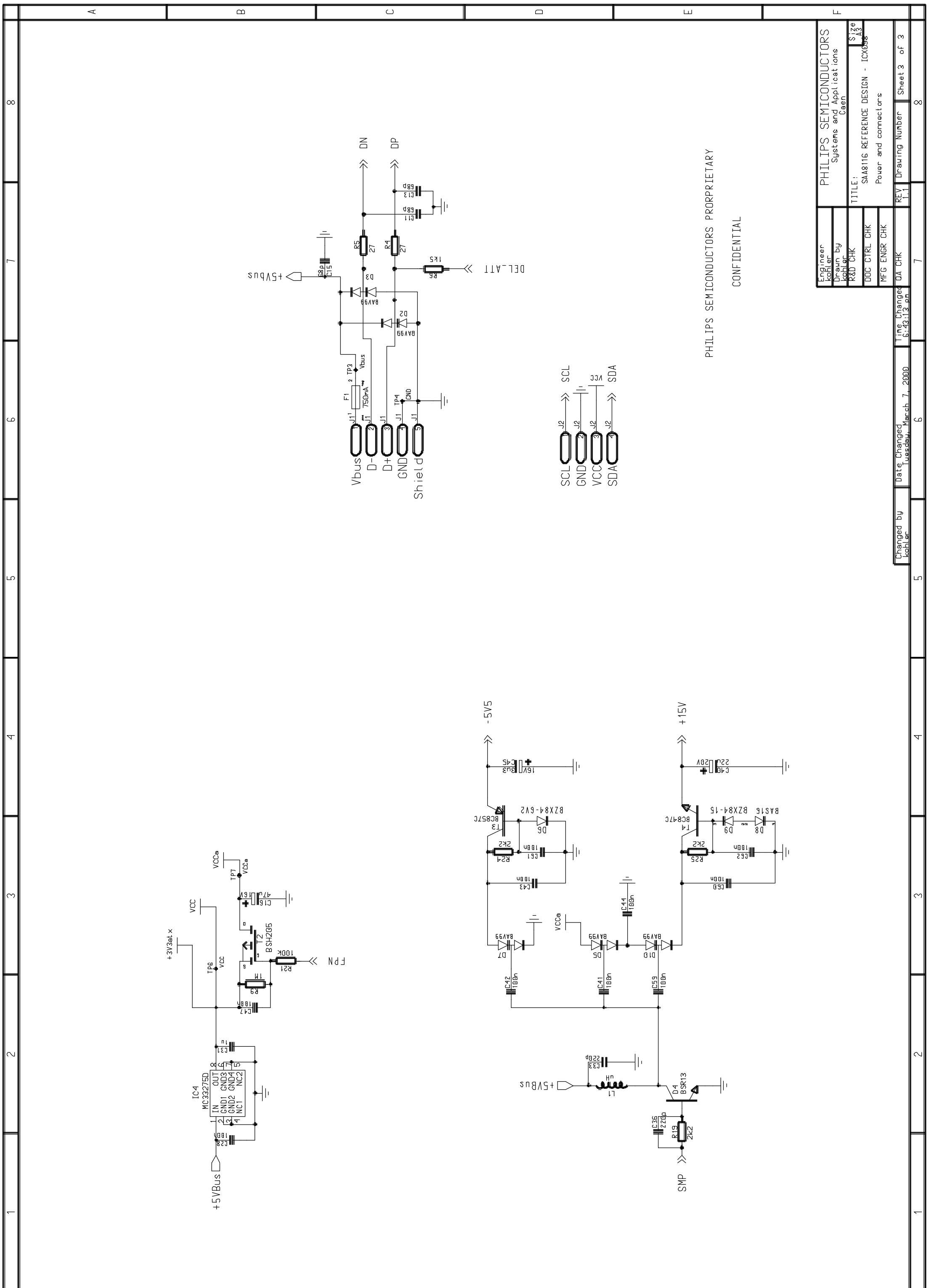
CONFIDENTIAL
TDA8787AHL
ICX098AK
CXD1267AN
BF861B

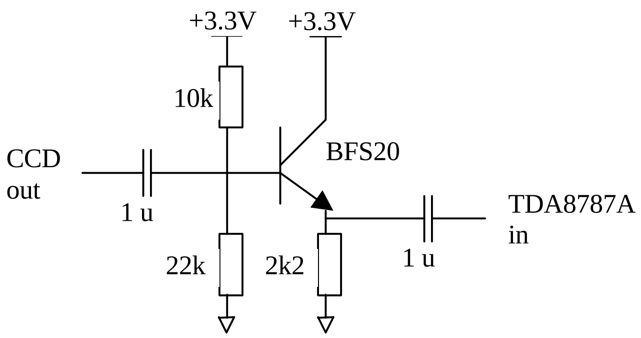


3.3 CCD supply

Instead of the switch mode power supplies, the CCD supplies generation circuitry can be replaced by a DC-DC converter such as the Maxim MAX685, which is able to deliver two regulated output, one positive up to 24V and one negative up to –9V, with only one inductor and a few external resistors and capacitors.

3.4 CCD buffer

This reference design uses a MOS buffer to amplify the CCD signal, based on a BF861B transistor. A bipolar buffer could also be used :



In the case of the Sony ICX098 CCD, the CCD already contains a buffer. The outside buffer can then be removed. Then care must be taken during the camera alignment procedure, that the CCD output never exceeds the maximum amplitude of the TDA8787A input. This is done by setting the nominal AGC value.