**Preface (in a hindsight)**

The notes below were written before I was pointed to a site that had the datasheet for A015AN04 (the TFT-LCD panel used in the camcorder) and saw the trace of the PCB Version B1 provided by `MUOTUC` (thanks a lot for the trace and the links!), so, as expected, I did get some things wrong. However, with the benefit of a hindsight, we can analyse which methods worked and which did not, which lines of thought were correct and which were misleading. This preface is an attempt at such an analysis.

There is not much to talk about in the case of the imager: it was known what the chip itself was, what signals to expect on what pins and it was possible to visually inspect the imager itself to see at least some traces on the imager PCB. As a result, the pinout for the imager was entirely correct.

The TFT-LCD panel, however, was a totally different story. The assumption that pins 2 through 9 were parts of a charge pump, as well as the traces of the surrounding circuits were completely correct. Also correct was the reason for this redesign—the reduction of the BOM. One incorrect guess involved the FRP and VCOM pins. It turns out that pins 1 and 10 were VCOM and FRP respectively.

In retrospect, this would have been a reasonable hypothesis: the documentation for A015AN02 states that by adjusting the bias on the VCOM pin and the AC part of the signal, one can control the contrast and brightness of the panel. Thus, this bias must be provided externally (R63, R69). However, I should also point out that the goal was a minimal setup that would get us a working LCD and pins 1 and 10 were not a concern.

What I did get completely wrong was the control pins (29–31, 27). It turned out that pin 27 is now a NC, not SEL0. Moreover, there is no SEL0 pin at all in this panel! It is curious to note, though, that according to the revision log for the specs for A015AN04, pin 27 *used to be* a SEL0 pin but was made into a NC after the introduction of the corresponding bit into the *serial interface*.

This is what I got completely wrong: the 'logical' pins 29–31 are now parts of a serial interface and not just static 'setup' pins. Hints about this setup were several: when playing with covering these pins up, I noticed that no matter which one of them was disconnected, the result was always a compressed display (of course! the LCD was not initialized and thus stayed in the default UPS052 mode). Even though some behavior was consistent with the static setup (say, the 'reset' mentioned in one of the notes), it was clear that just by setting these pins to certain logical levels was not enough to control the panel.

Would this have led to a disaster when the LCD panel was set up to work independently from the camcorder? Not likely. A short test of several setups of pins 29–31 would quickly reveal that the *timing* of their setup was important. If the idea of the serial interface did not pop up at this time, a quick DSO capture of the power on sequence would have uncovered it.

After writing this, I could not resist and check all these facts. After setting the DSO to trigger on the falling edge, it was easy to see the clock, CS, and serial data patterns on the screen (including the fact that every transmission consists of 16 bits). It would have taken a bit more work to figure out the pattern for initializing the LCD (borrowing a logic analyzer would have made it easy) but in itself, this task is rather trivial (well, one unpleasant part is to fugure out how to read three signals at the same time: I am talking about soldering three thin wires at 0.5 mm pitch here). Unfortunately, the frequency of the serial clock (about 400 kHz) makes it impossible to use PC parallel ports as a 'poor man's logic analyzer' (coupled with some home-brewed Linux drivers—works very well for deciphering the codes for IR remotes!) but using any microcontroller board would serve the purpose (a $39 Z8Encore! would work just fine).

Thanks to `MUOTUC`, I have been able to find the docs on U7 and UPS051. I have to say, I should have realized that it is quite likely that whoever designed the camcorder would order all the voltage regulators/converters from the same company. A quick look at their marking info would have revealed the identity of U7. Oh, well.

Last remark: the same site that has the documents for A015AN04 has a note saying that this part will be discontinued July 2005. Enjoy it while it lasts.

In any case, here is the cool part: for $30 ($20, if you get a card/coupon) you can get a very nice TFT-LCD screen and an imager which can be used completely independently in a number of projects. If you do not mind a bit of careful desoldering, a 256Mb SDRAM and a 256Mb Flash come with it. There is still a chance that someone will figure out how to use the board as a multipurpose SBC (I wish Zoran were more forthcoming with their docs for Coach 7; we do know it has MIPS in its core: maybe someone will put Linux on it). Can you say 'robot vision'?

## AUO LCD-TFT pinout

Like a number of other people, I would like to use the parts of the camcorder for my other projects. In this case the pinout and the schematics become important, as one would have to build his own driver circuits for the imager, LCD, etc. This note is an attempt to figure out the pinouts and workings of the LCD panel. The TFT-LCD panel itself is made by AU Optronics (the same LCD is used in the still camera made by the company that made the camcorder). It is *not* A015AN02 V1 as was guessed by some people. For one, this panel has 33 pins, not 32 and the signals on those pins look totally different from what one would expect had it been A015AN02.

However, looking at the schematic given at the end of the spec for A015AN02 one cannot help but wonder why most components of the switching power supply were not integrated on the driver chip for the panel. Bulky things like the power MOSFET, inductors, and caps can be left outside but the inverter/doubler diodes, small transistors, etc, could be put inside the driver IC, thus reducing the parts count. I believe this is exactly what AUO did.

Pins 2 through 9 are the most interesting of the bunch. The high voltages appearing on some of these pins (12V DC) do not come from the outside. They are generated by the LCD panel itself (see Methodology below). I could find no inductors connected to the LCD (one exception: the backlight driver, formed by Q6, L9 and D10, where the gate of Q6 is controlled by the output of pin 12 through a resistor) so my only guess is that these pins are parts of the charge pump that drives the common electrode of the LCD. Pins 7 and 8 are probably the FRP and VCOM pins respectively (all pin names are references to the A015AN02 V1 datasheet); this guess is based on the sample schematic at the end of the specs for A015AN02 V1. Someone could probably explain the function of pins 1 and 10 as well but the panel works just as well with these pins left unconnected (see below) so I did not feel the need to work out an explanation just yet. Any help/advice is appreciated.

AUO also did away with a (tricky to make, I presume) bangap voltage reference for FB and instead probably uses a simple forward biased diode as a voltage reference (see notes for pin 14). After all, in this new design the switching power supply drives the backlight only. The reason I think so is there is no pin with 1.25V on it (the standard silicon bandgap); instead there is a pin with .6V on it (pin 14) used as a reference. Either that or they do use a bandgap with a weird referencing scheme.

Since I did not want to destroy the PCB, I had to resort to a number of nondestructive experiments. The nature of these experiments is explained below.

### Methodology

I performed several kinds of measurements: using a scope (a couple of times a DSO that I borrowed, otherwise I used a 60 MHz analog scope) to observe the signal on the pins and a continuity meter to trace which components are directly connected. The leads of these tools are too large for the pitches involved (0.5 mm) so I fashioned a crude replacement out of a busted 10X probe and a sewing needle. The frequences involved are not that high, so it worked quite well.

In the notes below you will frequently see the words 'disconnected' or 'isolated' from the PCB. The way this was achieved (call me crazy) was with a very careful placement of extremely thin strips of packing tape (cut with an exacto knife) onto the pads of the flex flat cable of the panel. I also checked that the tape was, indeed, nonconductive. When I say '*from the LCD side*' or something similar it means that I measured the signal on that pad directly from the flat flex cable, while the pad itself was covered by the packing tape. This is to give me a better idea of where the origin of the signal was.

Finally, all this data refers to the $B_3$ version of the PCB (the only one I have for testing). The pin numbering refers to counting the pins *from the right* looking at the LCD side of the PCB with the USB connector pads at the top. Some measurements were made with the LCD disconnected completely. Comments appreciated (of course, all the speculations above could be completely wrong).

## Pinout

| Pin | Description (signals, etc) |
|---|---|
| 1 | $6V_{pp}(-3V$ to $3V)$ square signal at $\sim$ 10 kHz (see also Note 0) |
| 2 | 12V DC |
| 3 | $6V_{pp}(6V$ to 12V, i.e. DC value of 9V) (fuzzy) square signal at $\sim$60 kHz (also see Note 1) |
| 4 | $6V_{pp}(0V$ to 6V, i.e. DC value of 3V) (fuzzy) square signal at $\sim$60 kHz (also see Note 1) |
| 5 | $-$ 6V DC |
| 6 | $-$ 12V DC |
| 7 | $12V_{pp}(0V$ to 12V, i.e. DC value of 6V) square signal at $\sim$60 kHz (see also Note 2) |
| 8 | $12V_{pp}(-12V$ to 0V, i.e. DC value of $-6V)$ square signal at $\sim$60 kHz (see also Note 2) |
| 9 | 6V DC |
| 10 | $6V_{pp}(0V$ to 6V, i.e. DC value of 3V) square signal at $\sim$10 kHz (see also Note 0) |
| 11 | 0V, connected to the common ground |
| 12 | DRV pin; $3.3V_{pp}$, $\sim$340 kHz signal, PWM driver (see General notes below) |
| 13 | VLED pin, 7.5V DC |
| 14 | GLED/FB pin, 0.6V DC |
| 15 | probably main power, 3.3V DC, directly connected to U7 |
| 16 | 0V, directly connected to the common ground |
| 17 | 3.3V DC, a power source probably controlled by the main processor (see also Note 3) |
| 18 | HSYNC pin, $3.3V_{pp}\sim$18.7 kHz negative going square signal |
| 19 | VSYNC pin, $3.3V_{pp}\sim$71 Hz negative going square signal |
| 20 | DCLK pin, $3.3V_{pp}\sim$6.7 MHz square signal |
| 21 | DATA |
| 22 | DATA |
| 23 | DATA |
| 24 | DATA |
| 25 | DATA |
| 26 | DATA |
| 27 | $\sim$0.1V DC, one of the control pins, probably SEL0 (see Note 4) |
| 28 | $\sim$3.3V DC, one of the control pins, probably (see Note 5) |
| 29 | $\sim$3.3V DC, one of the control pins, probably (see Note 6) |
| 30 | $\sim$3.3V DC, one of the control pins, probably (see Note 7) |
| 31 | $\sim$3.3V DC, one of the control pins, probably (see Note 8) |
| 32 | probably main power, 3.3V DC, directly connected to U7 |
| 33 | 0V DC, directly connectedd to the main ground |

## Notes

*Note 0.* Pins 1 and 2 produce a very clear square signal, in phase with each other. When either one (or both) is covered, there is no noticeable effect on the picture, however, when the signal on the pins *on the*

*LCD side* is measured (while the pins themselves are disconnected from the PCB), two different signals are observed: ∼10 kHz, $6V_{pp}$ clear square wave on pin 10, and a fuzzy (unstable) ∼10 kHz, $4V_{pp}$ square wave on pin 1.

*Note 1.* Pins 3 and 4 are the most interesting. When captured by a DSO, the signal on these pins looks like a square wave whose period *and* duty cycle are changing a little. The top of the square wave has a small (∼0.5V) 'jump' in the middle, suggesting a switching diode clamp. The only outside connection I could find was a capacitor (C31) connecting the two pins. Disconnecting these pins from the PCB makes the picture completely white. If after that, one briefly shorts pins 1 and 2 an almost normal (but grainy and washed out) picture appears. All the voltages/voltage swings are about half of their table values. It may be due to the fact that the internal capacitance of the LCD circuitry is large enough to sustain the charge pump operation (after all, an ordinary LCD does not need that much current to switch its polarity) but not enough to start the pump (just a guess).

*Note 2.* Pins 7 and 8 are also connected to each other through a capacitor (C38) with no other apparent connections. When isolated from the PCB, the signal on *pins 3 and 4* becomes a very clear ∼60 kHz square wave.

*Note 3.* Pin 17 is directly connected to (probably the drain of) Q9 whose other electrode (probably gate), in turn, is directly connected to Q10. Another electrode of Q9 (probably its source) is connected directly to U7 (which, I presume is a voltage regulator). The pin is also decoupled to the ground via C43. Now, one of the electrodes of Q10 just 'disappears into the night' which, I assumed, means it is connected to the MCU. The whole scheme looks like a processor controlled power switch.

*Note 4.* Pin 27 is pulled to the ground by the 10 kΩ R85. When looked at closely, it shows 10 ms bursts of high frequency noise every 10 ms (that is about a 50 Hz pattern) of $∼0.05V_{pp}$.

*Note 5.* Pin 28 is pulled high by the 10 kΩ R77 (which is connected to the 3.3V pin of U7).

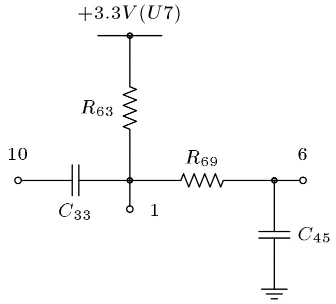
*Note 6.* When pins 29, 30, and 31 are isolated from the PCB the picture is distorted but crisp and almost recognizable (about half of the screen is lit up, into which the whole picture is compressed). The signal on pins 3 and 4 becomes a clear ∼12 kHz square wave. When only pin 29 is isolated, and then set to ground after the camcorder turns on, the screen goes blank, it is probably the PWRDN pin.

*Note 7.* When pin 30 *only* is disconnected from the PCB, the compressed picture is upside down (how do I know? it just happened that my battery ran low when I did this test, so the blinking 'battery low' icon appeared in the top right corner instead of the bottom right; the icon looked compressed like the rest of the picture but clearly recognizable). This is probably the UD pin but how can the rest be explained (see A wild guess below).

*Note 8.* When pin 31 is disconnected from the PCB *before* the camcorder is turned on, the effect is similar to what happens when 29, 30, and 31 are all disconnected. When it is disconnected *after* the power up, however, there is no effect.

*General notes.* Pin 9 is decoupled to the ground via C44, pin 5—via C37, pin 2—via B12 (B probably stands for (B)ypass). The schematic below shows some other interesting connections between different pins. It would be nice to have a full trace of the PCB; some dedicated souls are working on this right now, I cannot wait to see the results and thank them for their efforts. Before then, I had to rely on indirect tests to check that the connections I found were likely the only ones. One of the tests I used was to charge the capacitors with the LCD removed and check the charge several minutes later. In all cases the capacitors did not lose any detectable charge indicating that there were indeed no other connections.

In the schematic on the right, C45 is a pretty large cap, also the resistors, R63 and R69 are picked so that the bias at pin 1 is approximately 0V, so C33 is just a decoupling capacitor, to get rid of 3V DC at pin 10.



The behavior of the PWM driver is consistent with the design of A015AN02. Instead of having a traditional PWM where the duty cycle is varied continuously, AUO chose to implement a state machine that produces only a few discrete duty cycles, allowing the LCD driver to quickly ramp up the charge. This consistency leads us to a wild guess below.

*A wild guess.* It is known that the LCD in the camcorder emulates the UPS051 interface (thanks to the people who dug through the firmware, `morcheeba` in particular). In the datasheet for A015AN02 one has to pull pin 27 low to switch to that interface. It it curious to note that the only pin pulled low in this LCD is also pin 27. It could well be that pin 27 is the SEL0 pin on this LCD panel as well which would explain the strange behavior of pins 29 through 31. This guess has one flaw, however: the trace width for pin 27 indicates that it is supposed to carry significant current, like one of the power pins.

### OV7660-based CMOS imager pinout

Another interesting component of the camcorder is its imager. Fortunately, the imager chip itself is OV7660 made by OmniView Technologies (thanks, `morcheeba`). The only thing left is to find out which connector pins are connected where. All the pins in the table below are referenced by looking at the female connector on the main PCB with the USB connector edge up. The pins are counted clockwise starting with the one at the top right corner of the connector.

**Pinout**

| Pin | Description (signals, etc) |
|---|---|
| 1 | ground |
| 2 | SCC_I, periodic bursts when the picture darkens, synchronous with pin 3 |
| 3 | SCC_C, periodic 9 pulse bursts, when the picture darkens |
| 4 | AVDD, 2.89V |
| 5 | RESET, 0V |
| 6 | VSYNC, 30 Hz negative going |
| 7 | PWRDN, 0V |
| 8 | HREF |
| 9 | DVDD, 1.8V |
| 10 | 3.27V, I/O VDD (a bit too high, according to specs) |
| 11 | DATA (probably MSB) |
| 12 | DATA |
| 13 | DATA |
| 14 | DATA |
| 15 | DATA |
| 16 | DATA |
| 17 | DATA |
| 18 | DATA (probably LSB) |
| 19 | XCLCK |
| 20 | ground |
| 21 | PCLCK |
| 22 | ground |

*Notes.* It should be easy to determine the bit order of the DATA bus since OV7660 has a test mode in which a predetermined byte can be output on the bus. The guesses above were made by observing the signal on the pins when the scene is made very dark or very light.

It is harder to explain why the max parameters for the I/O VDD and AVDD have been exceeded. May be my scope/probe is not well tuned, may be it is because the datasheet is 'preliminary'. Again, any comments are appreciated. Of course, once the PCB trace is complete, everything in this table can be verified precisely. Notice there is no pin for the reference voltage here—this is because the requisite cap has been added to the imager PCB.

*Questions.* It would be of great help to have the trace of the whole PCB to finally answer the question of how to run these components in a different application. However, a few related datasheets would help, as well. I could not find almost any information on the UPS051 chip. It would be nice to know what the interface is. Also, it would be nice to find out what U7 is, exactly. It has JJ-F0Y markings on the package but I could not find any references to this SMD.