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# The Initial LIGO Timing System Nearly Fatally Flawed

CDS Meeting,  
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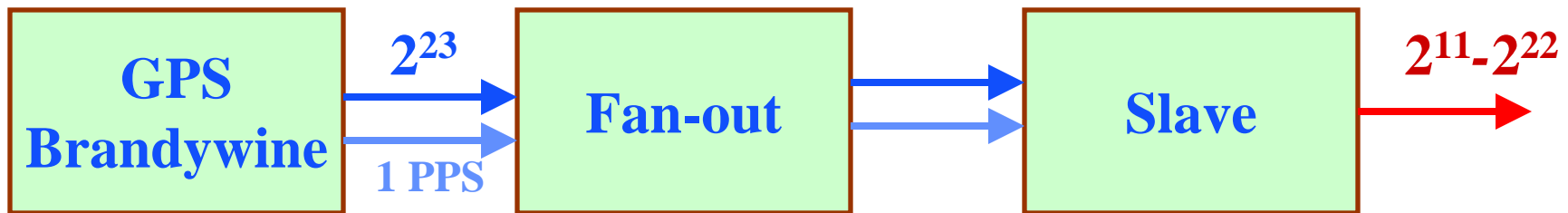
# Timing System Requirements

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- ❑ *The ability to reconstruct the arrival time of a gravitational wave signal with infinite signal-to-noise ratio shall be within 10  $\mu$ s of UTC.*
- ❑ *The timing jitter on the converter clocks shall not degrade their performance.*
- ❑ *Timing glitches, clock errors, servo system hick-ups and malfunctions shall be recorded.*
- ❑ *All oscillator frequencies shall be locked to UTC.*

***2<sup>N</sup> sampling clock → Impossible to buy off the shelf***

## Version 1



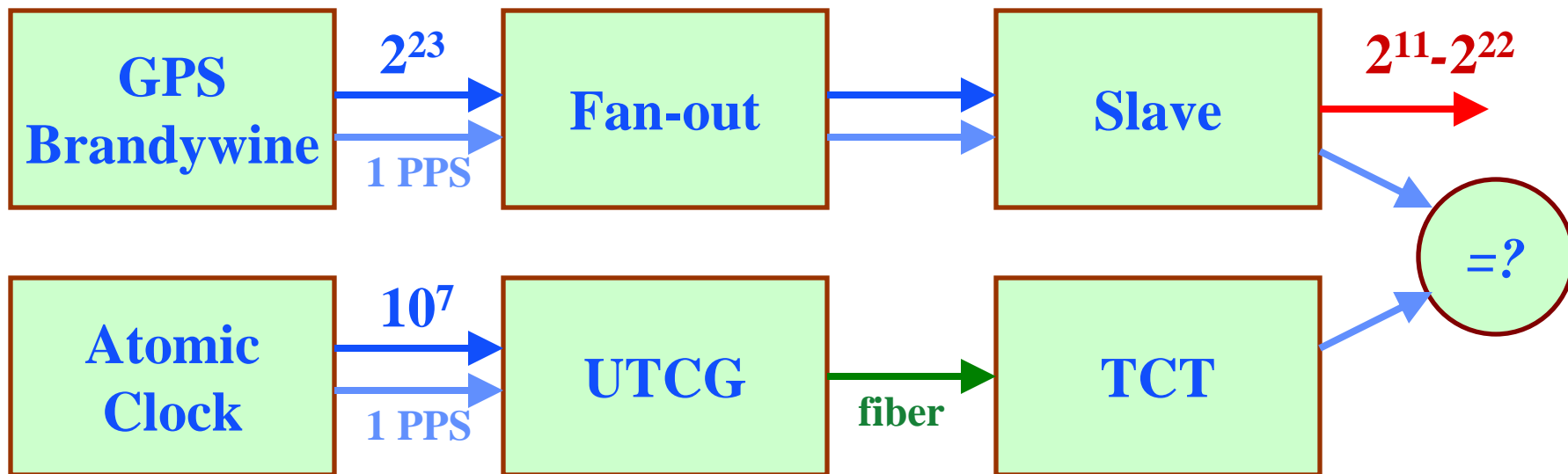
- ❑ 1 GPS master per (L)VEA
- ❑ Timing distribution signals are differential ECL
- ❑ Converter clock in most cases oversampled
- ❑ Converter clock starts at 1 second boundary

No true synchronization

Start-up problems (every time you boot, timing jumps)

Counting errors can go unnoticed for days, weeks, ...

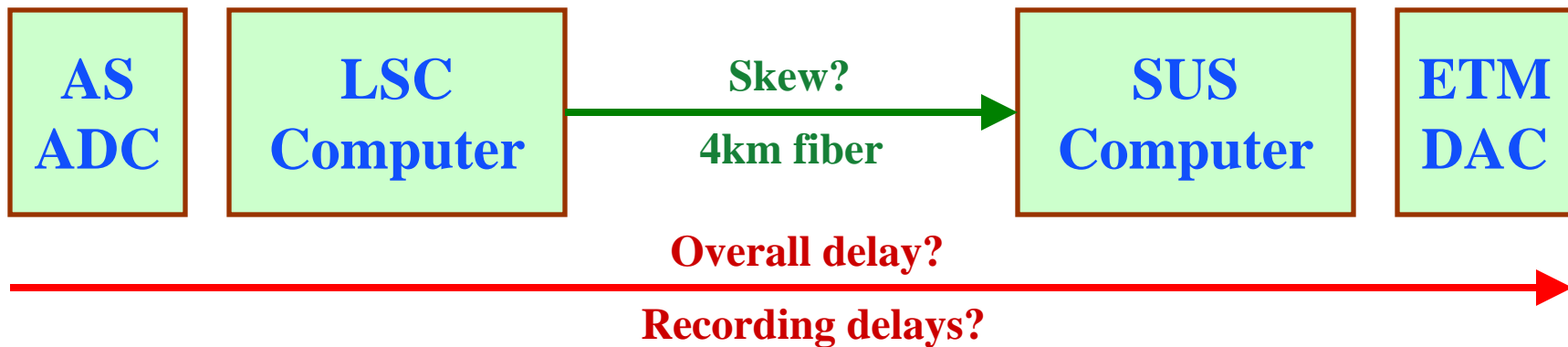
# Version 2



- ❑ 1 atomic clock per site
- ❑ 1 timing comparator per (L)VEA

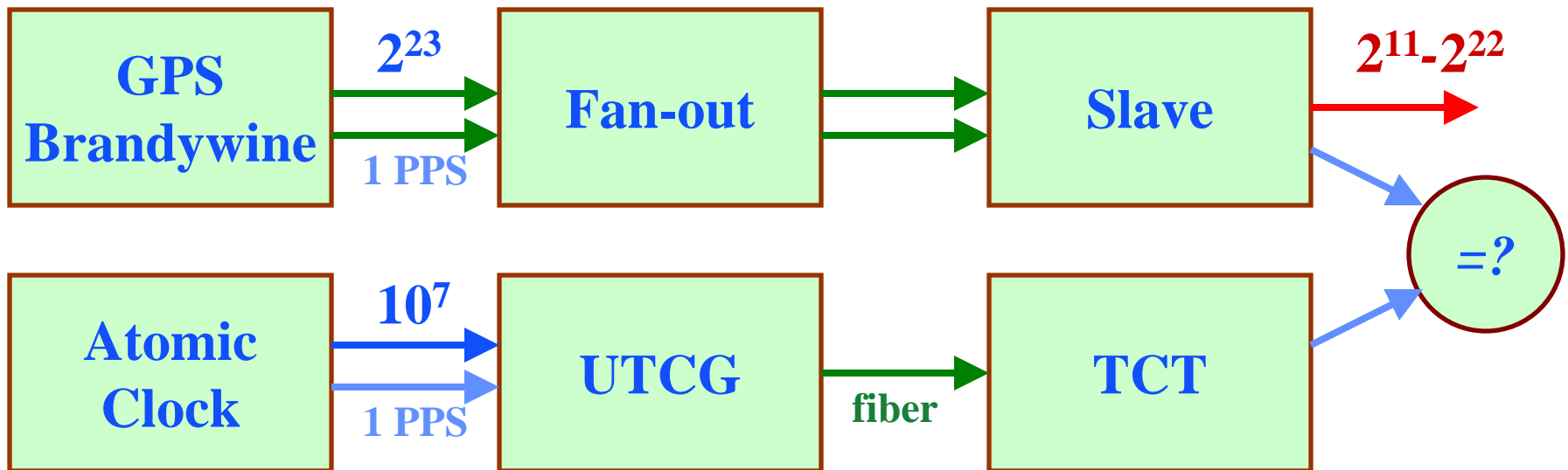
Doesn't solve converter clocking problems

# Transport Problem



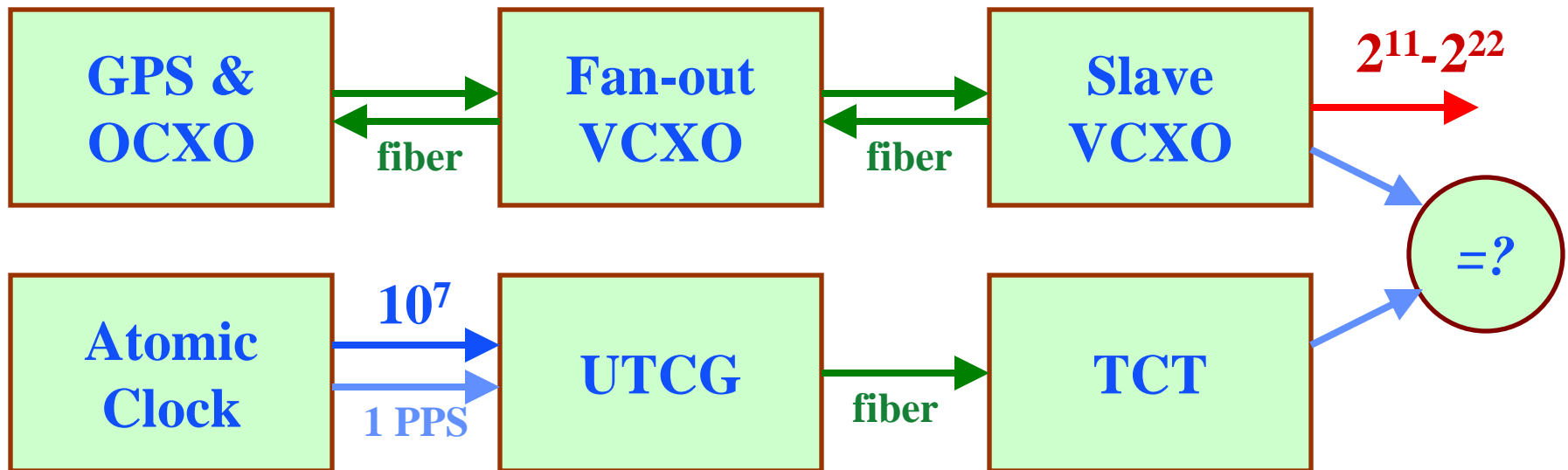
- ❑ Skew counters
- ❑ **Currently  $\sim 200\mu\text{s}$  not accounted for in the calibration!**

# Version 2½



- Replace ECL lines with fiber

# Version 3

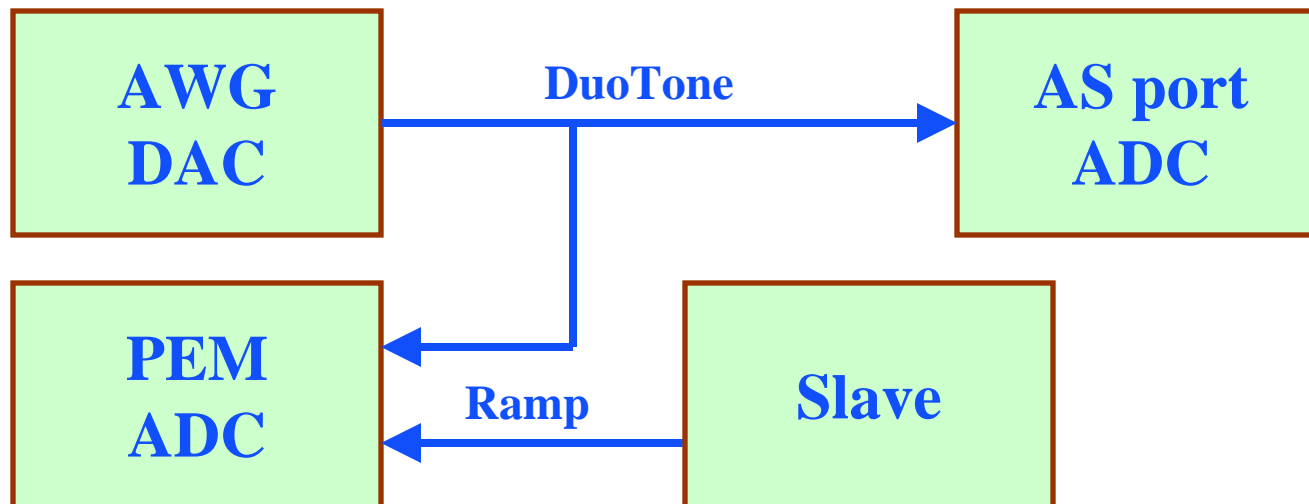


- ❑ 1 GPS/OCXO master per site (Symmetricom 58503B)
- ❑ Each fan-out and slave has its own VCXO clock
- ❑ Return fiber indicates the state of the slave clock

Timing errors and glitches are recognized and can be recorded

# Version 3+

- ❑ Time stamp with DuoTone
  - 960Hz and 961Hz (can resolve 1 PPS)
  - Ramp, IRIG-B, pulse don't work (harmonics)
- ❑ Only AS port ADC, DACs not covered





# Fiber Protocol

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## iLIGO:

- ❑  $2^{23}$  Hz clock
- ❑ Positive edges are used to lock VCXO in slave
- ❑ Negative edges are used to encode 1 PPS

## aLIGO:

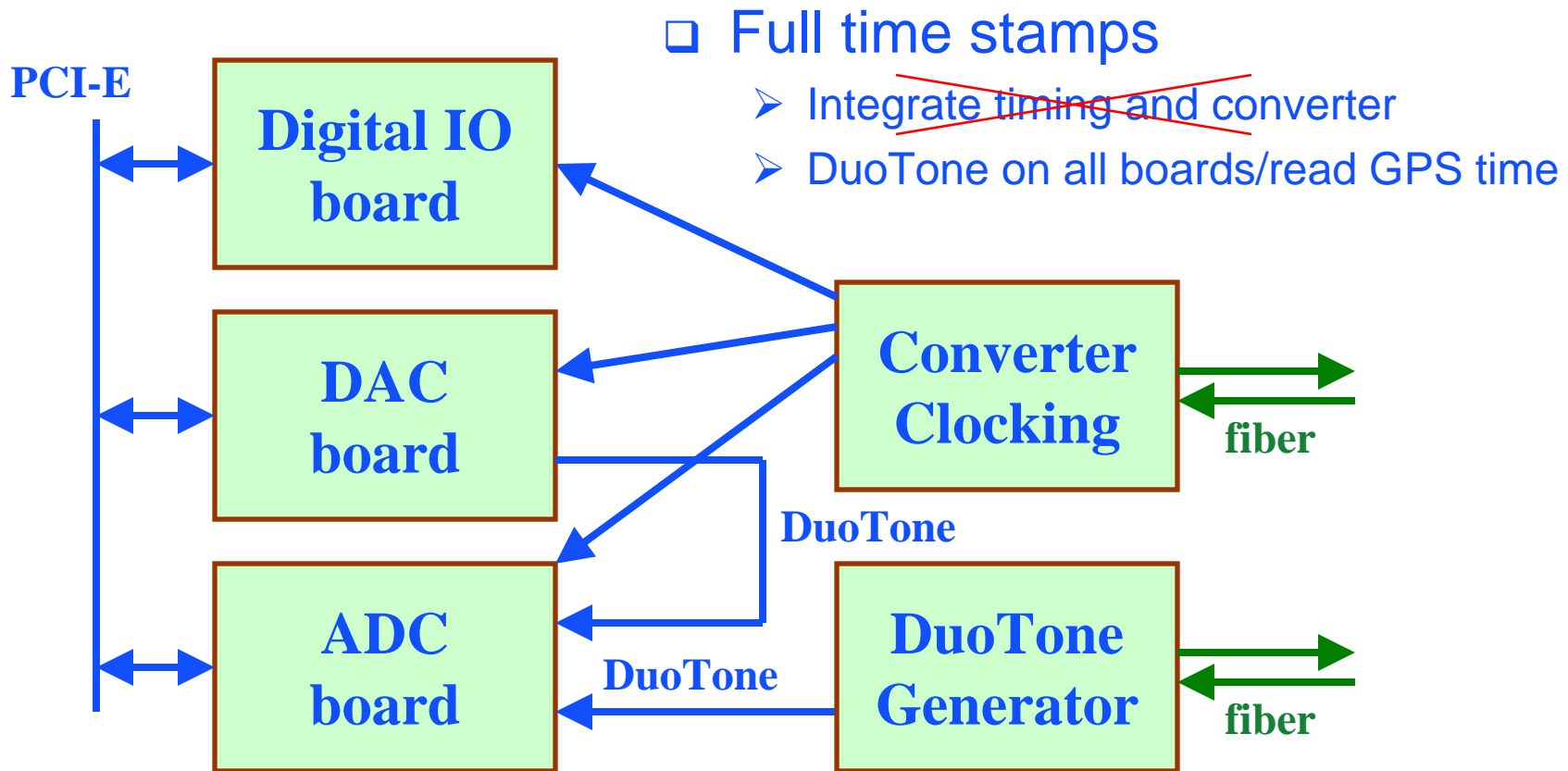
- ❑ Encode GPS time with negative edges
- ❑ Encode status and error bits with negative edges

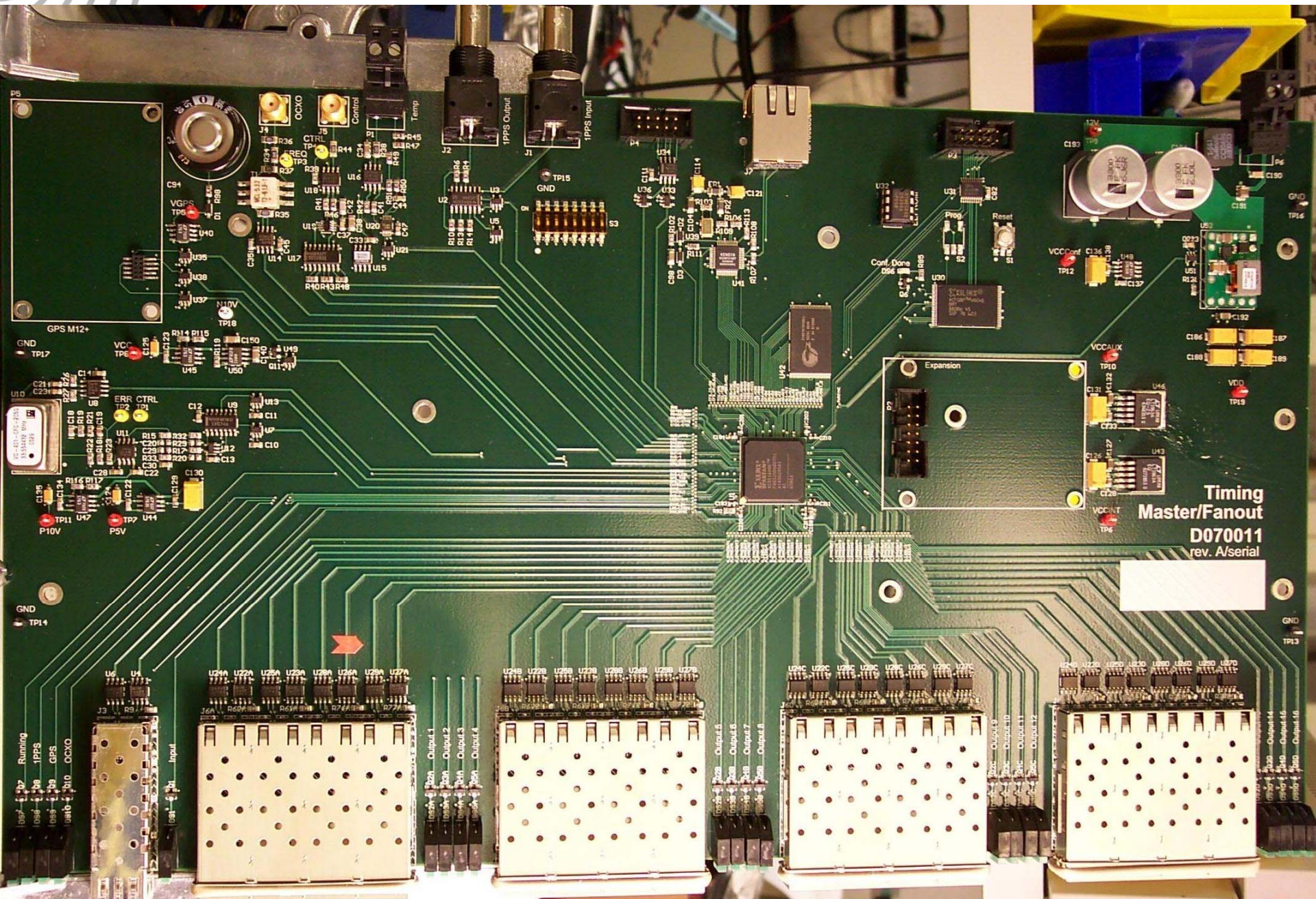
# Version 4.A (aLIGO)

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- ❑ Fiber based timing system
  - New FPGA based
  - All diagnostics sent back to master
  - Master interfaces a “EPICS” computer
  - Master integrates GPS receiver for time stamp
  - Master controls OCXO by digital servo
- ❑ Atomic clock as independent check (reuse current)
- ❑ Dedicated slaves
  - Converter clocking
  - DuoTone generator & 1 PPS comparator
  - XO locking

# Version 4.B (aLIGO)





Timing  
Master/Fanout  
D070011  
rev. A/serial



0007 - 007 Running  
0008 - 008 1PPS  
0009 - 009 GPS  
0010 - 010 OCKO

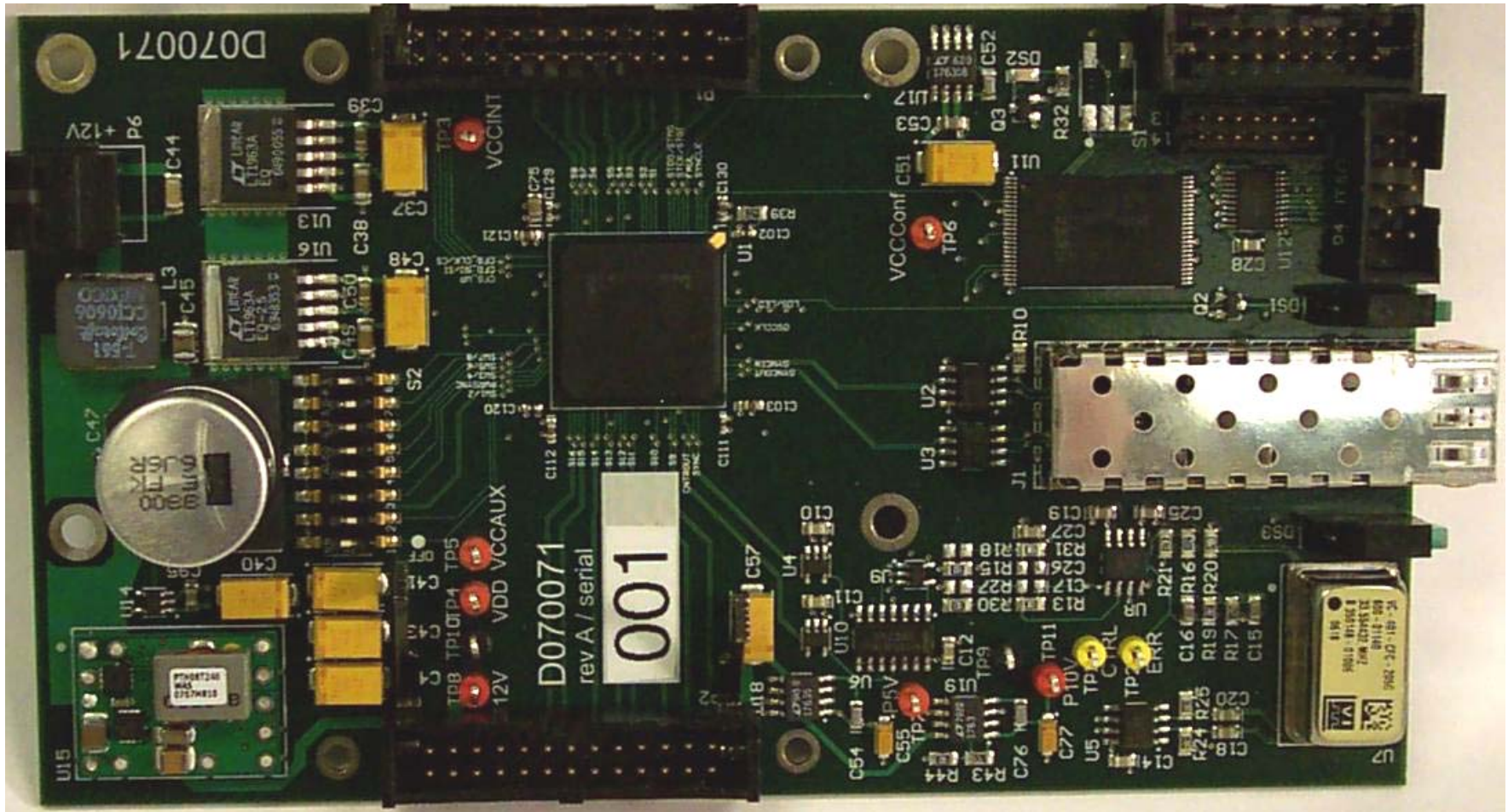
J6A U22A U22A U22A U22A U22A U22A U22A  
J6B U22B U22B U22B U22B U22B U22B U22B

Output 1  
Output 2  
Output 3  
Output 4  
Output 5  
Output 6  
Output 7  
Output 8

U29C U29C U29C U29C U29C U29C U29C U29C  
U29D U29D U29D U29D U29D U29D U29D U29D

Output 9  
Output 10  
Output 11  
Output 12  
Output 13  
Output 14  
Output 15  
Output 16

## Timing Slave (6" x 3.5")



# Conclusion

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- ❑ Persistent problems:
  - Timing jumps on reboot (problem resurfaced in fast ADC)
  - Lack of timing diagnostics
  - Lack of reliable time stamps
  - Lack of qualification
- ❑ 200 $\mu$ s unexplained calibration delay
- ❑ Photon calibrator analysis only now started

**Full time stamps and reliable diagnostics are necessary for the next generation timing system**