

Problem Definition

- Convert a sequence of photon count measurements into a “steering” voltage for a Local Oscillator

Constraints

- L.O. Frequency resolution of $< 10^{-17}$
- Slewing capability of 10-11 (5 seconds)
- 10 volt output swing
- Gross long-term L.O. aging compensation
- 5-10 second update rate

Previous Method

- D/A converter, 16-bit, 20V range

01000:1 resistive divider

- 300pV resolution (<25 pV required)
- 200mV range
- Requires L.O. adjust every 80 days

New Method

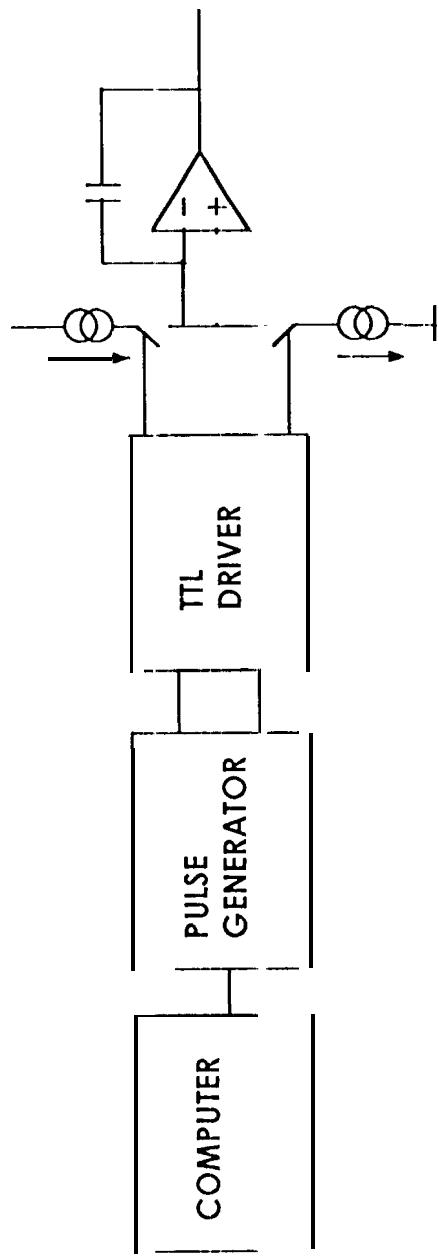
- 39-bit D/A converter?
- Don't need 10V range from cycle to cycle
- Use TAC form of Sigma-Delta converter
- Has desired resolution and 10V range

Implementation

- Computer/algorithm loop control
- Programmable Pulse-Width Generator
- Digital Drive Circuit
- Constant Current Sources
- Low-Noise Integrator

Block Diagram

- Time to Analog Converter



Details

- Computer provides pulse-width values to pulse generator
- Pulse width max=5 Sec @ 1 μ Sec resolution
- Pulse drives TTL logic enabling one of two current sources.
- Current is integrated, voltage applied to L.O.
- Small constant current cancels op-amp offset

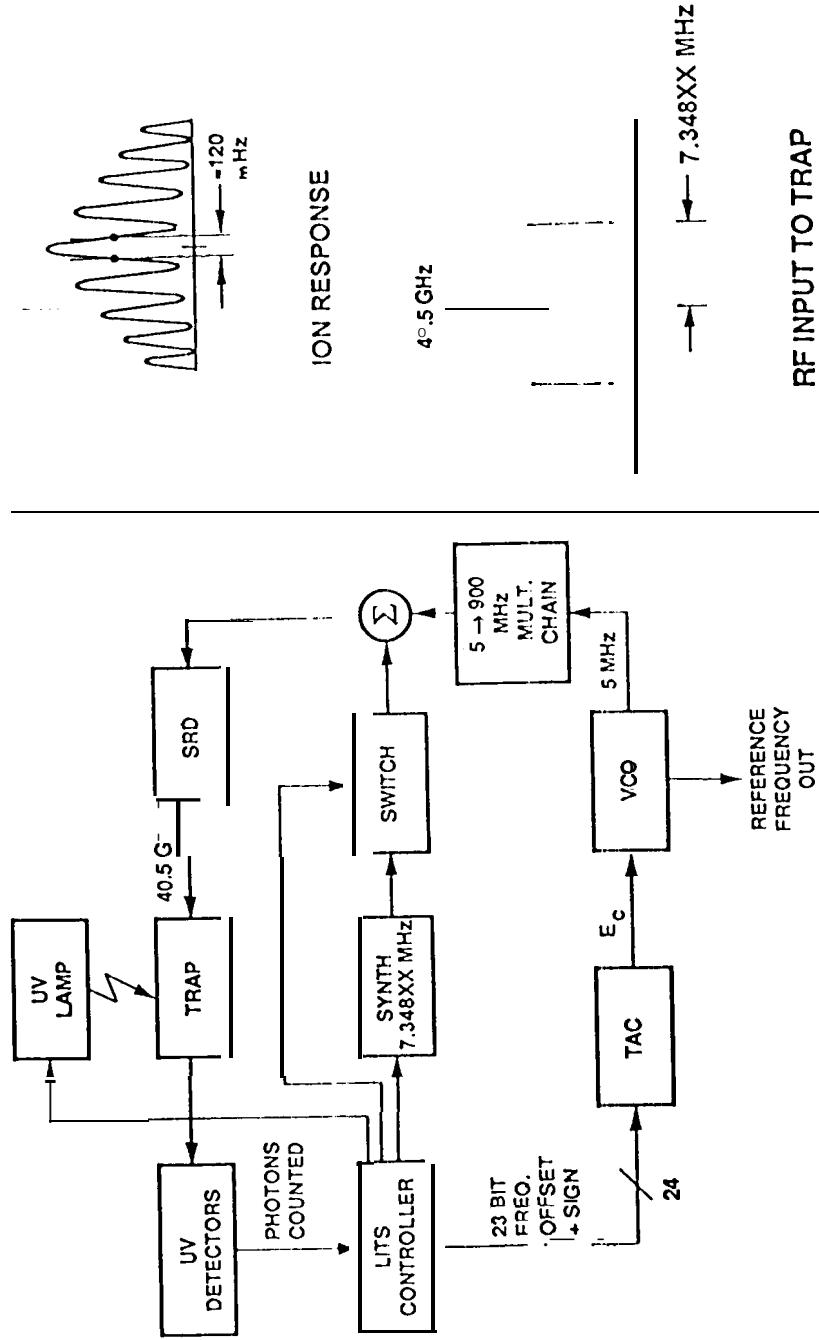
Results

Measurement	(Requirement)
● Max slew rate = 15mV/Sec (5mV/See)	
● Resolution = 6×10^{-20}	(10^{-7})
● 10 Sec var. < 2.5×10^{-15}	(10^{-14})
● Voltage Swing > 10V	(10V)

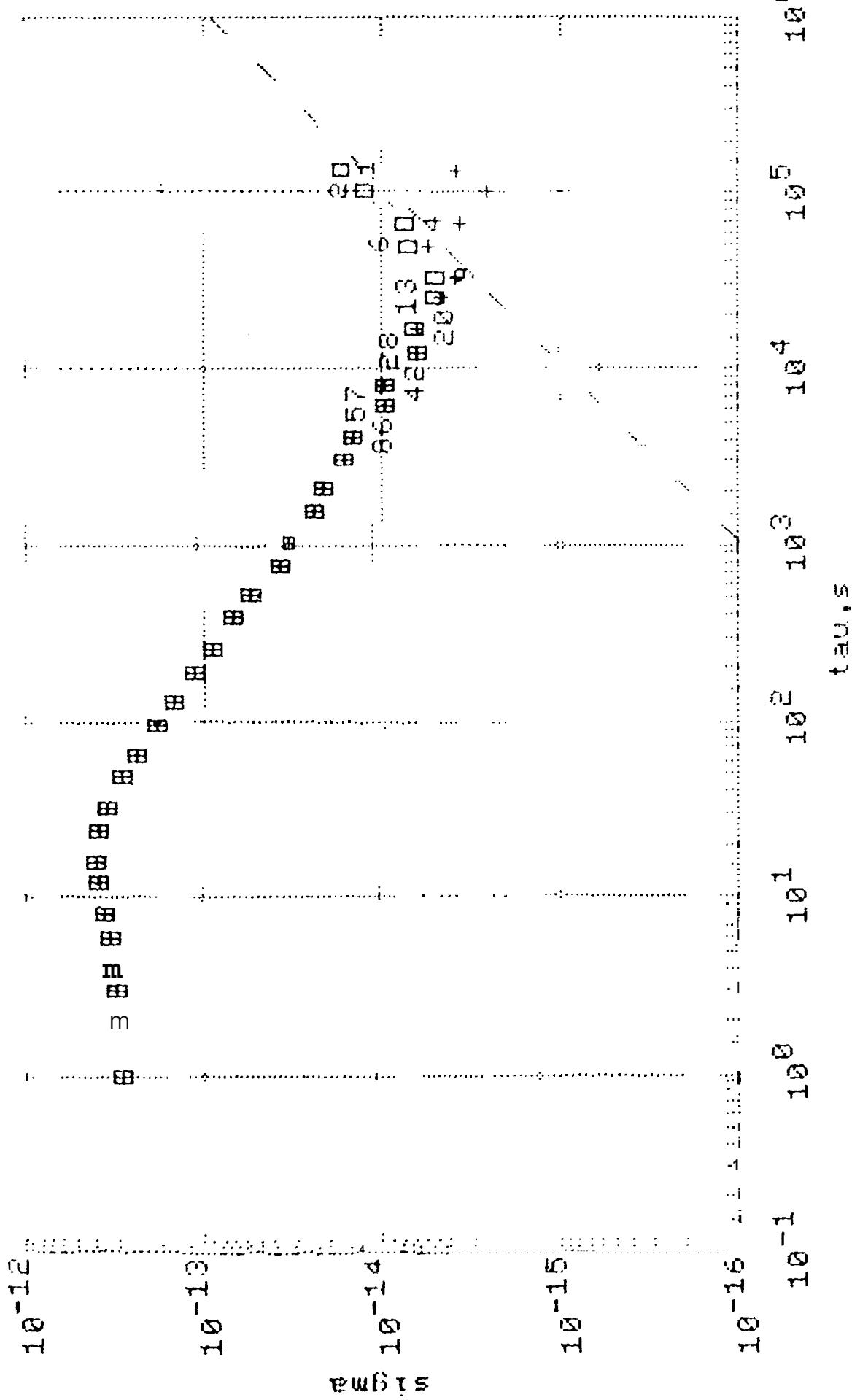
Challenges

- Temperature sensitivities forced control of integrator environment to <0.1 degree C
- Interference from 170 MHz transmitter required electrostatic shielding of TAC
- Not apparent that better temperature control provides better 10 second stability
- Current in-loop performance limited by VCO

LITS Frequency Locked Loop



950406_1031 Chn 1 Osc.freq.: 1.000E+08 Hz Period: 1.0015539570+00 s
 TRC-1 vs DSN-3
 Span: 950406.103121 to 950410.134122, 357001 s
 Here: 950406.103121 to 950410.134123, 357002 s
 Est. drift: 1.128E-14/s, Sigma: 5.373E-15 Gross □ Net +



950405_1256 Chn 1 Disc. freq.: 1.000E+08 Hz Period: 1.007568038D+00

TAC-1 vs DSN-3
Span: 950405_125651 to 950406_125651
Here: 950405_125651 to 950406_082331
Est. drift: 5.493E-12/d, Sigma: 1.381E-11

GROSS D Net +

