GRAYCHIP
DSP CHIPS AND SYSTEMS

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DDCs and DUCs for Wireless Communications

1998 ISART SYMPOSIUM

September 9, 1998

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GRAYCHIP DIGITAL UP AND DOWN CONVERTERS

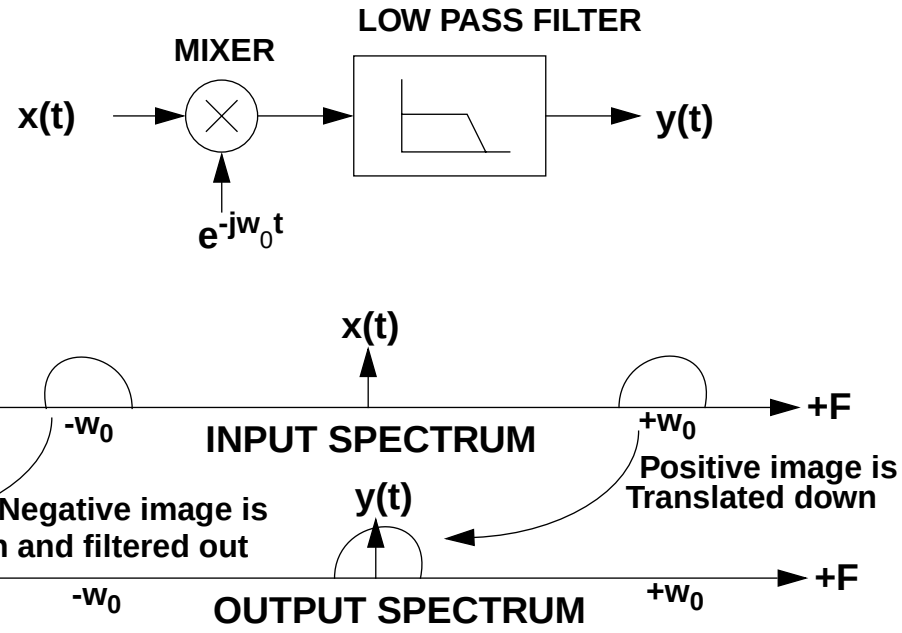
DSP CHIPS AND SYSTEMS

- **WHY DIGITAL INSTEAD OF ANALOG?**
  - **MOVES MANY TRADITIONALLY ANALOG FUNCTIONS INTO DIGITAL**
  - **EASIER MANUFACTURING AND MAINTENANCE (NO TRIMMING NEEDED)**
  - **HIGHER PERFORMANCE**
  - **FOR NARROW CHANNELS, SMALLER, LOWER POWER and COST**
    - **(for this purpose "NARROW" gets wider as a function of time).**
  - **FLEXIBILITY**
- **HISTORY**
  - **PRIOR to 1985 USED IN MILITARY/GOVERNMENT**
    - **multiple circuit boards, kWatts, <5MSPS, $200k each**
  - **1985-1990 PROPRIETARY CHIP SETS**
    - **proprietary 2-3 chips per DDC, 2-6Watts, 10-50MSPS, $500, $1,000 each, military customers**
  - **1990-1995 COMMERCIAL CHIPS**
    - **Single chip, Graychip & Harris, 1Watt, 50-70 MSPS, $100 each, commercial uses**
  - **CURRENT (1996-1998)**
    - **0.25Watt/channel, 50-70 MSPS, $10/channel, commercial use dominates**
  - **FUTURE (2000)**
    - **Wider bandwidths (support for WCDMA, LMDS, MCNS, etc.), better SFDR (for GSM)**

DOWN CONVERTER OVERVIEW

MOST BASIC FORM

- **BASED ON WEAVER DEMODULATION**



- **COMPLEX MIX DOWN AND THEN LOW PASS FILTER**

OPTIONS

IMPULSE BLANKER

SYNCHRONIZATION

RESAMPLER

NARROW BAND MIXER

CARTESIAN TO POLAR

FM DISCRIMINATOR

LOOP CLOSURE FOR DEMODULATION

CORRELATORS

FRONT END SWITCHING

DDC KEY SPECIFICATIONS

- **NCO**
  - TUNING RESOLUTION
  - SPUR FREE DYNAMIC RANGE - some cellular systems want > 110 dB
  - PHASE OFFSETS AND SYNCHRONIZATION - critical for beamforming
- **FILTERING AND DECIMATION**
  - FILTERING STOPBAND
  - DECIMATION RANGE
  - FILTERING STAGES
  - MAXIMUM OUTPUT BANDWIDTH
- **ADDITIONAL FUNCTIONS**
  - RESAMPLING - allows oversampled output, independence of input and output rates
  - DEMODULATION SUPPORT - rectangular to polar conversion, FM discrimination, etc.
  - SYNCHRONIZATION - especially for beamforming
  - FRONT-END SWITCHING - to allow visibility to multiple ADC's
  - IMPULSE BLANKING - especially for HF environment

A COMPARISON OF VARIOUS DDCs

	Fin Max	Max BW Out	SFDR	Dec Range	Comments
GC1011A	70	0.875	75	64-64k	Introduced 1989
GC1012A	70	28	75	2-64	Power of two decimation
HSP50214	65	0.657	98	4-16k	+ resampler, rectangular to polar conversion, FM discriminator
GC9001	5	0.25	100	16-16k	+ resampler, CORDIC, NB mix, transmitter
GC4014	62.5	1.563	95	32-64k	four channels
AD6620	65	~0.4	100	?-16k	can also do 2 channel diversity at 1/2 rate

Not released yet

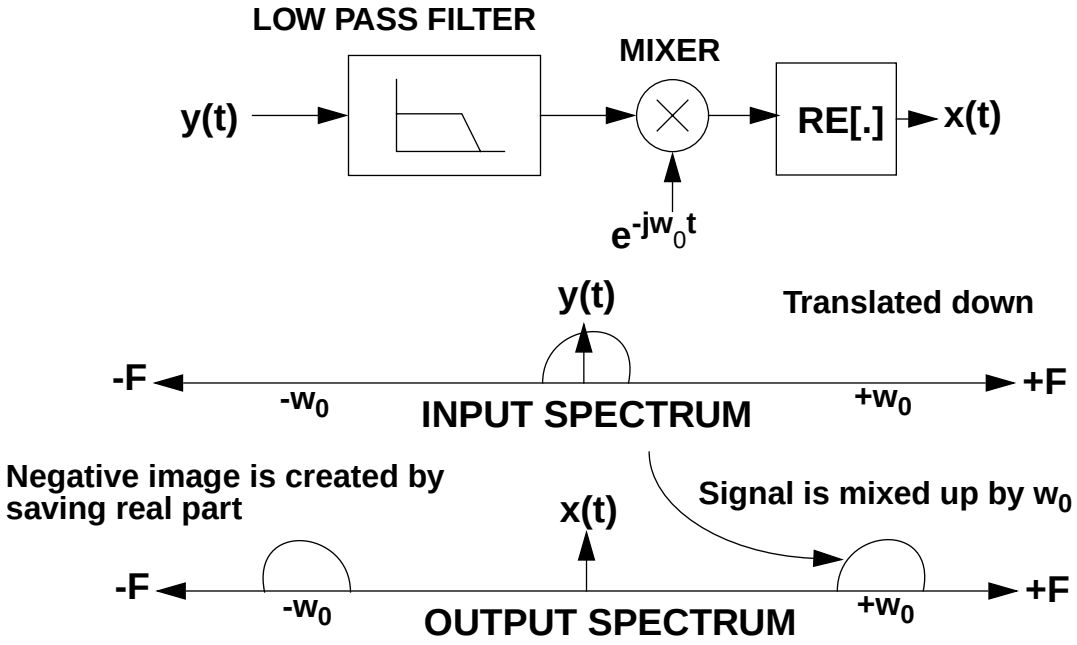
GC1016	500	20	90	4-168	Coarse frequency resolution
GC4016	70	4.5	115	12-32k	Four channels + resampler
GC1116	300	30	90	4-512k	can do 2 channels at 1/2 rate

Many DDCs allow a trade-off between stopband and maxBWOut. Here maxBWOut is estimated for a 130 tap decimate by four final filter, bandwidth is 80% sample rate.

AD6620 is publicity shy. Information is based on preliminary datasheet.

UP CONVERTER OVERVIEW

- **BASED ON WEAVER MODULATION**



- **OPPOSITE OF THE DEMODULATOR**

OPTIONS

SUPPORT FOR FM/FSK/GMSK

RESAMPLING

SYNCHRONIZATION

SUMIN/OUT

A COMPARISON OF VARIOUS DUCs

	Fout Max	Max BW In	SFDR	Int Range	Comments
GC9001	5	0.25	90	16-16k	+ receiver, NB mix, resampler
GC4114	62.5	1.56	85+	32-64k	Four channels. Two channels can be slaved for double bandwidth.
HSP50215	52	0.4	85+	4-?	Resampling architecture. Estimated 400 kHz at 80dBstop, 800kHz at 65dB stop.

Not released yet

GC1116	300	30	90	4-512k	can do 2 channels at 1/2 rate. Can do higher BW at a lower rate.

First filter data input span of 31 samples for GC9001, GC4114, and GC1116. The span is 16 for HSP50215.

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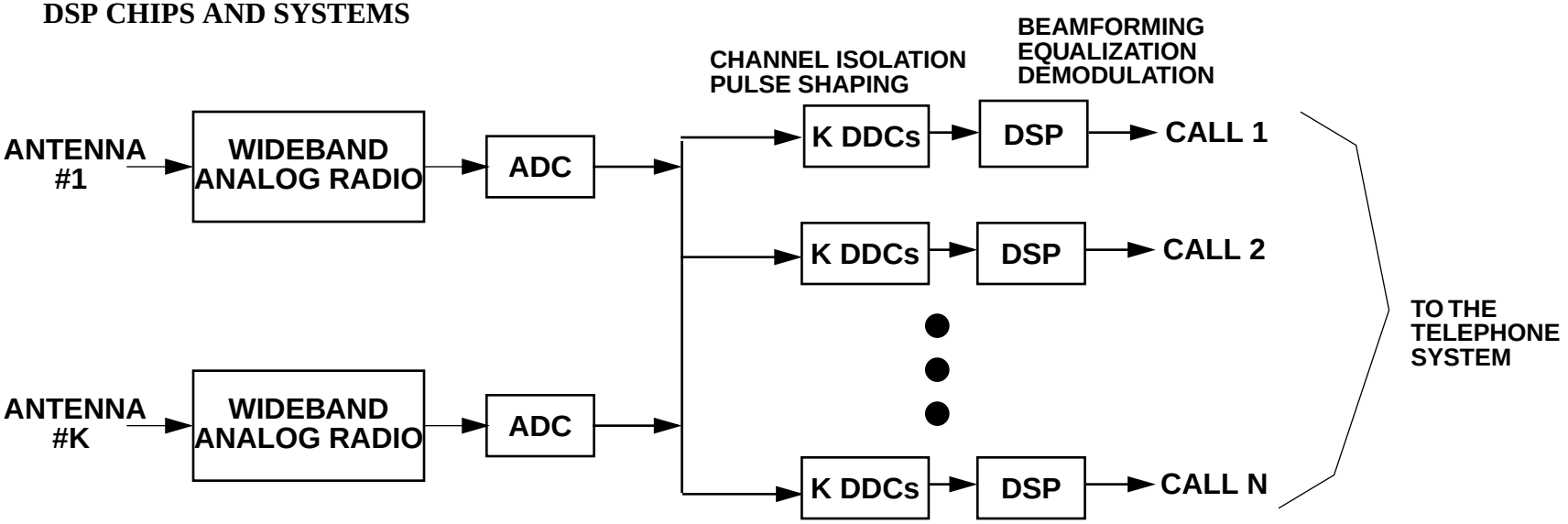
DIGITAL BASE STATION ARCHITECTURE



BEAMFORMED "WIDEBAND RADIO" DOWN-CONVERTER ARCHITECTURE

- SINGLE WIDEBAND ANALOG RADIO PER ANTENNA DOWN-CONVERTS COMPLETE CELLULAR FREQUENCY BAND
- 10 TO 100 DIGITAL RECEIVERS EXTRACT INDIVIDUAL CALLS FROM THE WIDEBAND RADIO OUTPUT
- ADVANTAGES:
  - FREQUENCY ALLOCATION ON DEMAND OPTIMIZES CELL USE.
  - BETTER FIDELITY, SMALLER, LESS POWER, LOW MAINTENANCE
  - CAN BE USED FOR ALL CELLULAR FORMATS (GSM, AMPS, CDMA, etc.)
  - LOWER MOBILE TRANSMIT POWER REQUIRED, BETTER FREQUENCY REUSE

HIGHER INTERMEDIATE FREQUENCIES

- HIGHER RECEIVER IF CAN BE PROCESSED USING UNDERSAMPLING IF THE A/D FRONT-END IS WIDE ENOUGH W/O LOSING TOO MUCH PERFORMANCE

- HIGHER DUC SAMPLE RATE OUT IS DESIRED
  - TRANSMITTER IF REQUIRES HIGHER DIGITAL SAMPLE RATE
  - OVERSAMPLED DATA INTO D/A TO IMPROVE SPUR PERFORMANCE
  - ❖ GC1116 WILL BE SUITABLE FOR THIS PURPOSE
    - TYPICALLY 1/2 GC1116 PER D/A.
    - MAY ALSO ALLOW PREDISTORTION FOR POWER AMP.

GRAYCHIP GC1016 WIDEBAND DDC

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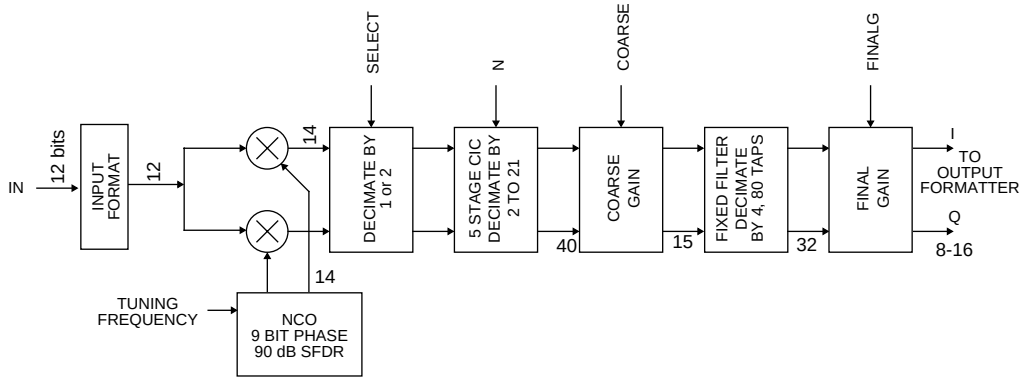

- **UP TO 500 MSPS INPUT (ECL, PECL, LVECL, CMOS)**
- **UP TO 25 MSPS COMPLEX OUTPUT**
- **TARGETED FOR RADAR APPLICATIONS**

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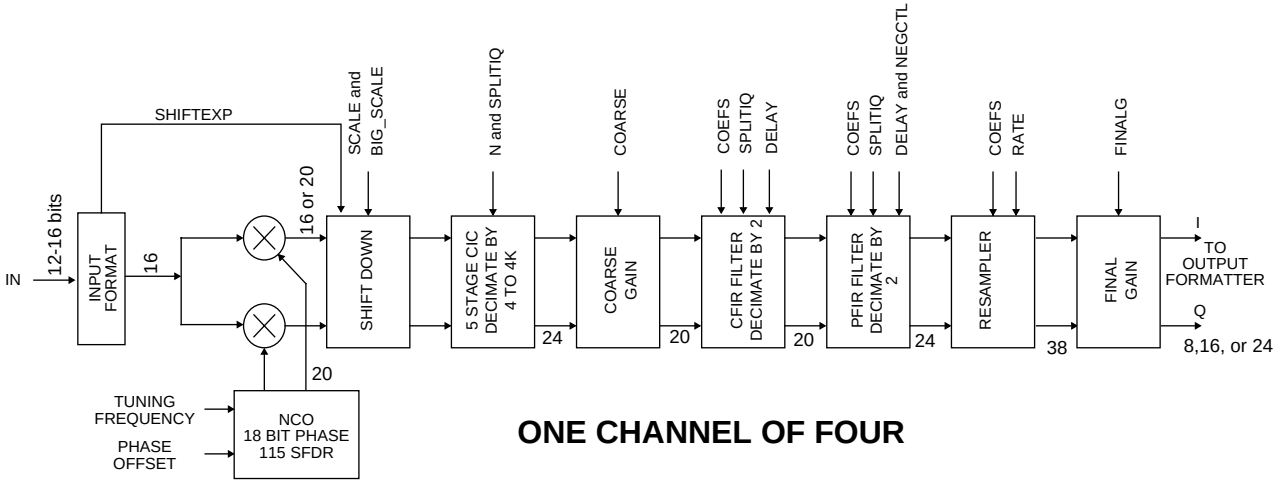
GC4016 UPCOMING QUAD DDC



ONE CHANNEL OF FOUR

- **FOUR FULLY INDEPENDENT DDC's IN 100TQFP**
- **FOUR NARROW BAND OUTPUTS, TWO WIDER BAND OUTPUTS, OR ONE WIDE BAND OUTPUT**
- **RESAMPLING FOR ARBITRARY OUTPUT RATES AND OVERSAMPLING**
- **~175 mW / CHANNEL for GSM @ 61.75 MSPS**
- **SUPPORTS GSM, IS136/TDMA, AMPS, NMT**
- **SUPPORTS FOUR IS95@2x, TWO IS95@4x OR ONE IS95@8x**
- **SUPPORTS WCDMA, MCNS**
- **OPTIONAL PARALLEL OUTPUT**