key portions of real applications (e.g. digital filtering algorithms).

- *Technology-specific benchmarks* are devoted to point out the main differences of devices belonging to the same technological family (e.g. Programmable Electronic Performance Cooperative or PREP benchmarks [7]).

Application and synthetic benchmarks tend to assess the behavior of a processing device when different types of operations are carried out. Accordingly, these kinds of benchmarks are suitable to estimate the average performance of very involved, general-purpose systems (e.g. personal computers), but they are unable to provide significant results when single devices have to implement a specific set of algorithms, as it usually occurs in most digital signal processing applications. On the other hand, technology-specific benchmarks are usually so specialized not to be useful for cross-technology comparisons. As a consequence, only kernel benchmarks are suitable to estimate univocally the performances of different digital signal processing solutions. Generally, a well-designed kernel benchmark test has to be:

- *representative*: the performance result should be summarized by a single number, usually referred to as index of performance;
- *reliable*: the larger the index of performance is, the faster the device under test (DUT) has to be;
- *reproducible*: running several times the same benchmark program on a given device under the same conditions, performance results should not change considerably (except for uncertainty contributions);
- *portable*: the benchmark has to be independent of a particular technology or architecture.

Besides these basic properties, a kernel benchmark test should also be:

- *meaningful*, because it is pointless to measure an uninteresting or rarely used feature;
- *linear*: any index should be proportional to real performance;
- *easy to use* so that it can be used frequently and correctly;
- *vendor independent*, i.e. independent as much as possible of the influence of external subjects which may be interested in benchmarking results (e.g. for marketing purposes).

Some published results suggest that performance indexes referring to digital signal processing devices can be effectively measured by means of basic algorithms such as numeric filtering, FFT, matrix calculations or operations on bit streams [3, 4]. Among them, FFT algorithms are most valuable benchmarks because they own all the properties mentioned above. In fact, FFT benchmarking is:

- *representative* because several numerical indexes can be calculated from FFT processing times;
- *reliable* as processing time does not depend on the kind of input data;
- *reproducible* because execution time associated with a given device depends only on the algorithm chosen and on the clock frequency [5];
- *portable*: FFT is basically a mathematical operation;
- *meaningful* because FFT is widely used in many digital signal processing applications;
- *linear*: doubling the performance means halving the execution time (or doubling data rate as explained in next section);
- *easy to use* because, once FFT is implemented, only transformation times need to be measured regardless of input values;
- *vendor independent* as standard FFT algorithms are not proprietary.

Besides these features, plenty of documentation is available about different FFT implementations both in terms of design choices and performance analyses. Hence, using a given FFT algorithm as a kernel benchmark not only eases the comparison between devices belonging to different technologies, but allows also verifying the truthfulness of the performance claimed by device manufacturers.

3. PERFORMANCE METRICS

Basically, the performance of any digital signal processing application can be measured in terms of data rate (*DR*), which is referred to as:

$$DR = \frac{N}{t_{proc}} \qquad \text{[samples/s]}, \qquad (1)$$

where N is the amount of processed samples and t_{proc} is the processing time (e.g. the time to compute an FFT algorithm on N=1024 complex samples). Notice that this parameter is reliable because it is inversely proportional to the processing time, so that its value grows linearly with performance, as expected intuitively. An equivalent index to express the processing capabilities of a given digital signal processing device is the so-called Real-Time Bandwidth (*RTBW*) that represents the maximum bandwidth with which an effective analog input signal can be processed in real-time, without loss of information. According to the Nyquist theorem [4], *RTBW* is numerically equal to half of *DR*, provided that t_{proc} is the effective FFT processing time, i.e. it is not affected by bus overhead or latencies associated with external memory operations. Under these assumptions, once FFT algorithm has been chosen, the estimated *RTBW* value depends only on the characteristics of the DUT, such as the clock frequency and the operation execution speed. Conversely, if FFT computation time is slowed down by poor bus performance or by other system bottlenecks, the *RTBW* value provided by (1) could be appreciably overestimated.

In addition to *RBTW*, another valuable parameter to assess the performance of a digital signal processing device is the Architectural Efficiency (*AE*), which is referred to as: